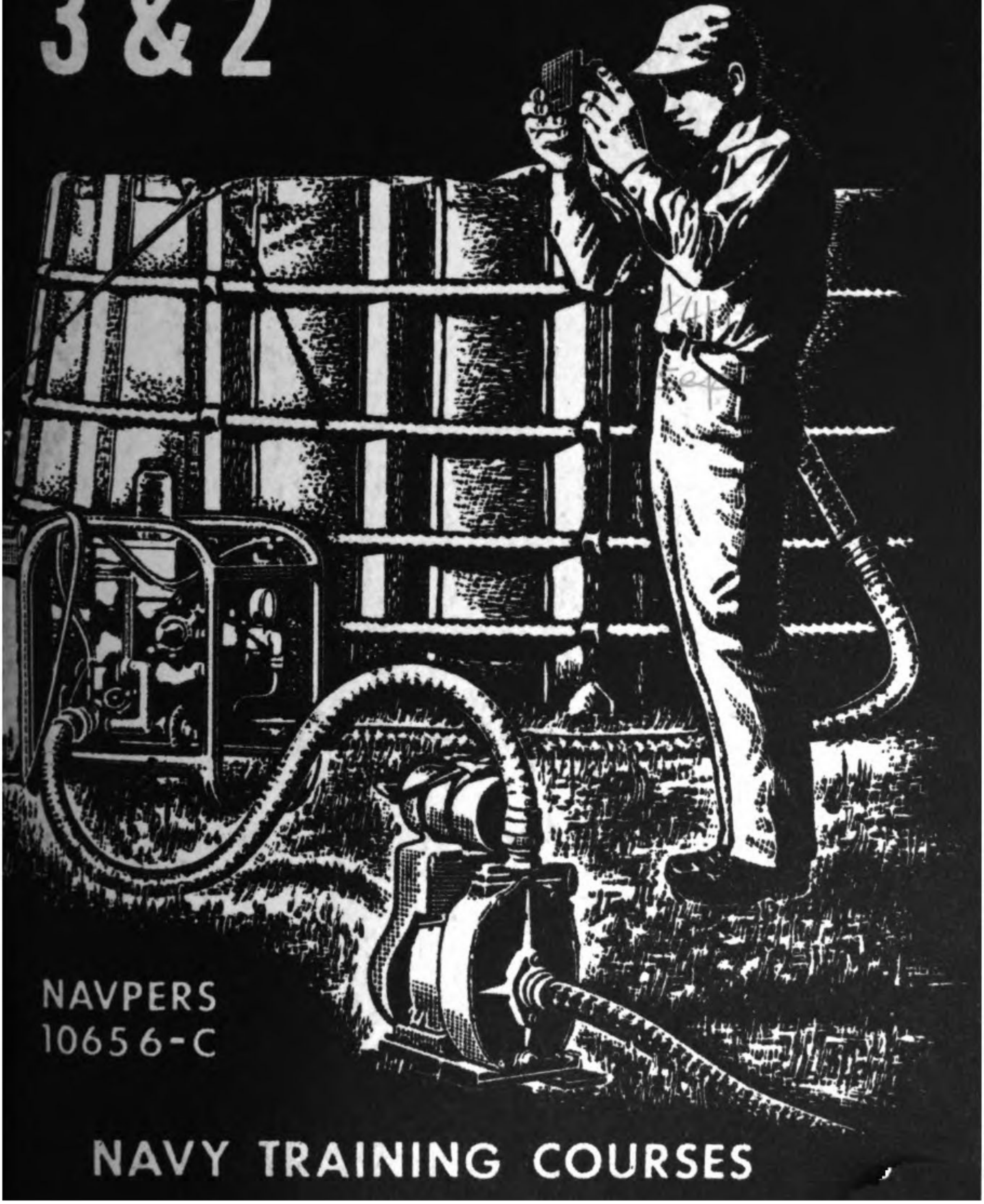
UTILITIES MAN
3 & 2



NAVPERS
10656-C

NAVY TRAINING COURSES

U.S.

UTILITIES MAN
3 & 2

PREPARED BY

U.S BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos. as E–6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.		Records of Practical Factors, NavPers 760, must be completed for all PO advancements.			
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.
	12	9 mos.	15 mos.	21 mos.	24 mos.	36 mos.	42 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.
DRILLS ATTENDED IN GRADE#	48	27	27	45	54	72	108
	24	16	16	27	32	42	64
	12	8	13	18	20	32	38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48	14 days	14 days	14 days	14 days	28 days	42 days
	12	14 days	14 days	14 days	28 days	42 days	42 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

Basic Hand Tool Skills (metal working skills only), NavPers 10085

Blueprint Reading and Sketching (Chapters 1–5, 13), NavPers 10077-A

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for supplementary reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to your rate follows:

Correspondence

Number	Title
CB 290	*Physics I*
CB 794	*Principles of Diesel Engines*

Self-Teaching

MB 290	*Physics I*
MB 794	*Principles of Diesel Engines*

* "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

PREFACE

This book is written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Utilities Man 3 and 2. Combined with a thorough study of the basic Navy Training Courses and the necessary practical experience, the information in this training course will prepare the reader for advancement in rating examinations.

The first chapter of this book contains general information concerning the work and responsibilities of the Utilities Man 3 and 2; a brief discussion on Seabee history, leadership, and battalion organization; and reference to a valuable supply of source material.

Chapter 2 discusses such topics as pipe materials, fittings, and duties having to do with the installation of a plumbing system. Chapter 3 describes various repairs and adjustments you can expect to find necessary in maintaining and servicing an existing plumbing system.

A discussion on common, temporary methods of sewage disposal at advanced bases is presented in chapter 4, while chapter 5 goes on to explain the more permanent-type of sewerage system plant facilities and operations. In chapter 6, you will be introduced to the basic principles and theory of refrigeration.

Chapter 7 will help you to understand the basic principles underlying gasoline and diesel engine operation. In addition, it will provide you with some very useful information on pumps and compressors.

Chapter 8 deals with some of the major processes used in various combinations in the treatment and purification of water. The subject of portable water treatment units is covered in chapter 9, and distillation units in chapter 10. Then, in chapter 11, the reader is briefed on what to expect in the way of routine duties in a water purification plant.

Chapter 12 is concerned with various topics relating to steam boilers; for instance, fundamentals of steam generation, types of boilers pertinent to Seabee operations, and various accessories and fittings commonly found on boilers. Chapter 13 deals with the operation and maintenance of steam boilers and outlines the procedure for making various boiler water tests.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the U. S. Navy Training Publications Center and the Bureau of Naval Personnel, with technical assistance from the Bureau of Yards and Docks.

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UTILITIES MAN

3 & 2

CHAPTER 1

MEET THE UTILITIES MAN

The Navy offers plenty of worth-while opportunities to the up-and-coming individual who is interested in getting ahead. Navy Training Courses—such as the one you have here—provide an excellent example of the opportunities you have for self-improvement. A careful study of this book will aid you considerably in acquiring a useful technical knowledge of the utilities field, and help prepare you for advancement in rating. With the advancement you will benefit, of course, from an increase in pay. The Navy likewise will benefit since the new skills and knowledge of the utilities field will make you a more valuable member of our Nation's defense team.

Each advancement in rating carries with it added responsibility, and before being promoted you must fill all the requirements of the higher job. Navy leaders realize that maintaining the supremacy of our Navy—the strongest in the world—depends in large part on filling billets grade-by-grade with competent, qualified men. Giving responsible jobs to unqualified persons would be like placing square pegs in round holes, and Navy officials know the disastrous results which could follow such a practice.

The need is for men with BRAINS, BRAWN, SKILL, and KNOW-HOW. Such men are essential when it comes to manning ships, establishing beachheads, piloting planes, building advanced bases, and performing numerous other giant-sized tasks vital to the defense of our country.

The utilities man plays a vital role in Seabee operations. It may seem, ordinarily, that his services are taken for granted—especially as long as things are functioning smoothly. But just let a breakdown occur in some utility like the heating or plumbing system, and the utilities man is a mighty important man to have around.

Before proceeding let us explain that the term "utilities," as applied to a Navy base, refers to the plants, systems, and equipment which provide those services essential to the health and welfare of personnel.

Utilities Man is included in the group VIII ratings of the present rating structure along with Surveyor, Construction Electrician's Mate, Driver, Mechanic, Builder, and Steelworker. These are called the Construction, or Seabee, ratings.

SCOPE OF DUTIES

The principal duties performed by Utilities Men may be broken down into six areas, as follows:

1. Installation, operation, maintenance, and repair of pumps, stationary steam boilers, and water distillation and purification equipment;
2. Operation and maintenance of water-supply and sewage-disposal equipment;
3. Installation and operation of stationary prime movers used to furnish utilities at advanced bases;
4. Installing and making operating adjustments and repairs to refrigeration and air-conditioning equipment;
5. Plumbing and pipe fitting required at advanced bases;
6. Making prescribed chemical tests to determine safeness and potability of water.

Now that you have an idea of the scope of duties applicable to the Utilities Man rating, let us discuss some of the specific jobs which the third- and second-class Utilities Man should be able to perform.

UT 3

As a UT 3 you should be familiar with the proper technique of using hand tools required to perform elementary plumbing duties such as cutting and threading pipe. You should also know how to operate various types of utilities equipment found at advanced bases; for instance, pumps used for water supply, sanitation, and water purification; water distillation and purification equipment, and stationary diesel-powered prime movers.

Testing boiler and feed water is quite a contrast from laying pipe or fixing a leaky faucet; still it is a part of your job—and a very important part at that! Some paper work is also involved. Duties here include keeping operation logs on equipment in sewage disposal and water purification plants.

UT 2

Your job, at the second-class level, will involve the installation of water-distillation and water-purification equipment at advanced bases. You should be able to install brickwork for boilers and know how to repair furnace floors, walls, and lining of stationary steam boilers. In addition to cleaning boiler tubes, using power-driven equipment, you will have to replace defective boiler tubes. You must also be familiar with the methods of sewage disposal, as well as the types of sewage disposal equipment used at advanced bases.

QUALIFICATIONS

You will find the qualifications required for advancement in rating for the Utilities Man in appendix II of this book. These qualifications (or "quals") tell you what you have to KNOW and DO to become a UT; they have been taken from the *Manual of Qualifications for Advancement in Rating,* NavPers 18068 (Rev.). You may qualify already in some of these requirements; others you will learn through study and practice on the job.

You will find that both study and practice are necessary to prepare for advancement. Study the qualifications which apply to the rate for which you are striking. Strikers for UT 3 need learn only those quals marked 3 in the applicable rate column. A UT 3 studying for advancement should already know the quals marked 3 and must learn those marked 2.

Note also that the qualifications for advancement (appendix II) consist of Practical Factors and Examination Subjects. The term PRACTICAL FACTORS refers to qualifications which include minimum skills and abilities required for advancement, and which can be best demonstrated by performance. EXAMINATION SUBJECTS are qualifications which include the minimum knowledges required for work performance. How well you know these qualifications is best shown by means of a written examination.

THE SEABEES

The Seabees are construction forces of the U. S. Navy, the name being derived from the initials of the term Construction Battalion (CB). The Seabees were officially established on 5 January 1942. On 5 March of the same year the construction battalions were granted official permission to assume the name "Seabees." That is why 5 March is observed annually as the Seabee birthday.

The Seabees made a great contribution to the war effort in World War II, rightly earning for themselves the familiar slogan "Can Do!" Under officers of the Navy's Civil Engineer Corps, Seabees were assigned to construction projects in combat zones, where civilian contractors and construction workers could not be used very well under wartime conditions. The Navy realized that if these civilians were attacked and attempted to defend themselves, they would be regarded as guerrillas. Besides, most of them had never been trained in the art of war and probably would not have known how to defend themselves anyway.

The Seabees proved themselves equal to the colossal task assigned them. Docks, piers, living quarters, power plants, warehouses, bridges, and airstrips are only a few of the innumerable construction jobs performed by the Seabees. They participated in every major amphibious invasion of World War II and accomplished numerous noteworthy feats, both in the field of building under adverse conditions and in the field of combat.

The Bureau of Yards and Docks exercises technical control over the organization, equipment, and operational procedures of the Seabees. During wartime, Seabees are assigned the task of building advanced bases. In peacetime, their principal duties are maintenance and training.

The Navy maintains overseas bases even in time of peace—North Africa, Guam, and the Aleutians are examples of areas where such bases exist. The Seabees handle much of the maintenance and construction for these bases.

After the outbreak of hostilities in Korea, the Seabees were again called on to perform their primary function of building bases on foreign soil. In the event of another emergency, the skill and know-how of our fighting, building Seabees may prove more vital to the defense of our country than ever before. The more skill and knowledge you acquire in your rating, the greater the service you will be prepared to render your country if another emergency should occur.

BATTALION ORGANIZATION

Men with Seabee ratings may be assigned to shore stations in the United States, to overseas bases, or to fleet units other than the Naval Construction Forces. But most men with Seabee ratings are assigned to Seabee-type activities.

Seabee-type activities include mobile construction battalions (MCB's), amphibious construction battalions

(PhibCB's), maintenance units (CBMU's), and various kinds of detachments, some of which are created as the need arises and are then disestablished after accomplishing their purpose. When more than one battalion is needed for a big job, or when it is administratively desirable, a regiment or brigade command may be established, consisting of a number of battalions or other Seabee-type units.

The battalion is the basic Seabee organization, and MCB's are the principal units to which men in the group VIII ratings are most likely to be assigned. The officers of other Seabee-type units usually follow a battalion-type organization; therefore, the discussion that follows will be concerned with an MCB which will serve as a typical example of a Seabee unit.

Because of the great variety of missions, localities, and conditions under which the Seabees operate, the Navy has, for the most part, left the organization of the battalion up to the commanding officer. This flexibility permits the CO and his officers to gain the best use of men and materials for each operation. The Bureau of Yards and Docks, however, has published organizational guides to assist the CO. These guides, plus the experience of individual officers, and the Seabees as a whole, form the basis for battalion organization.

The battalion is usually considered as having two organizations: the military organization for muster, military formations, and, in time of war, defensive combat; and the operational organization for construction jobs.

The military organization is essentially an infantry battalion. Practically all battalions have the same basic military organization. This consists of five companies: Headquarters Company and four rifle companies designated A, B, C, and D. (See fig. 1–1.)

The operational organization of a typical MCB is a combination of a company system and a system of pooled labor. As in the military organization, there are five companies. Besides, a headquarters company, there are four

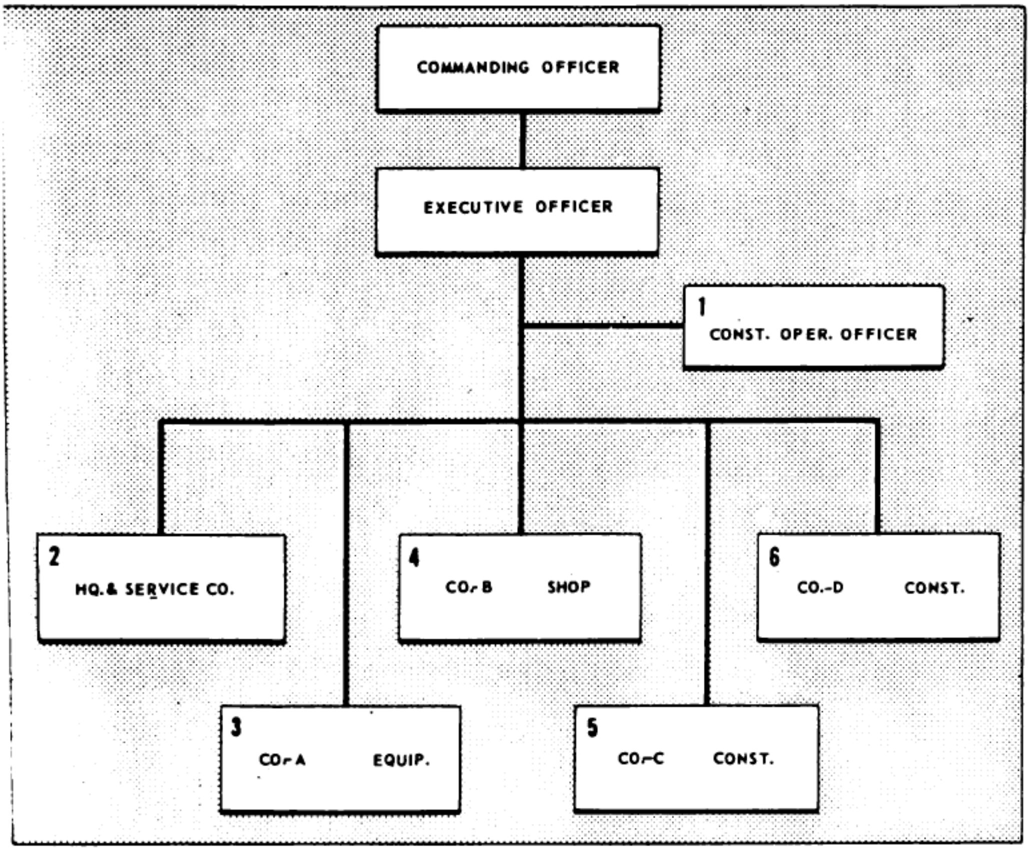


Figure 1–1.—Organization for operation of a typical mobile construction battalion.

operational companies, A, B, C, and D. Company A is an equipment company; Company B is a shops company; and Companies C and D are construction companies. The equipment company operates the transportation equipment assigned to the battalion. The shops company repairs tools, maintains camp utilities, and completes job orders submitted by the construction companies. The construction companies handle most of the construction work assigned to the battalion.

The operational organization is not a pure company system. One battalion officer is given authority over Companies A, B, C, and D during construction operations. This officer (usually the third-ranking officer in the battalion) is called the operations officer. He has authority to assign men from any of these companies to work with another company on a construction project. The operations officer also runs an engineering services section located in Headquarters Company.

Civil Engineer Corps officers engaged in construction work are under the control and direction of the operations officer. He might assign the commander of Company C to a project. As far as possible, men in Company C would also be assigned to the same project. However, men from other companies, such as equipment operators and perhaps shops personnel, might also be required for a time. While on the job, these men would receive their orders from the Company C commander. The operations officer would order them back to their companies at the completion of the job.

LEADERSHIP

The petty officer is more than a skilled craftsman. He is also a leader of men. In brief, a good leader is one who is able to obtain willing effort and teamwork from a group. As a third- or second-class PO you are not expected to be as skilled in the art of leadership as the first or chief. But once you become a petty officer you are pegged as leader material, so in your present grade it is important that you demonstrate an ABILITY TO LEAD OTHERS and make a willing effort to develop the potential qualities of leadership. Keep in mind that with each advancement in rating from here on you should be able to assume a bigger and more important role as a leader of lower-rated men.

In case you are one of those persons who somehow feels you simply don't have what it takes to be a leader, just remember that you CAN if you WANT TO badly enough. Forget that oft-heard saying about leaders being born and not made. There is too much evidence to the contrary! The average individual who sees the need for leadership and endeavors earnestly to develop the characteristics of a leader can do so. To help you develop traits commonly found in the type of leader which men consider it a privilege to follow, let us discuss some of the important aspects of the leader's job. In doing so let us note, in particular, certain desirable traits which the aspiring leader should strive to acquire, as well as certain undesirable traits he should endeavor to avoid.

The magnitude of the leader's job is indicated by the fact that every individual in any group is different. A technique which works well in dealing with a particular problem of one individual may fail miserably as a solution to the same type of problem in another man. To make allowance for individual differences, it will be necessary, of course, that you KNOW YOUR MEN.

One of the best ways to get to know your men is by talking with them. This does not imply that you must set yourself up as a quiz-master or go about prying into the private affairs of your subordinates. The idea is to talk with your men in a friendly, informal, and down-to-earth manner and let them know you are interested in them. When your men know you are genuinely concerned about what happens to them, they will want to come to you for advice should they have personal problems that interfere with their efficiency on the job. Too, they will be honest in letting you know the truth about how they feel toward working conditions, administrative changes affecting their liberty or other off-duty activities, and other such factors having a decided effect upon morale, efficiency, and production.

A chief characteristic of any good leader is a willingness to accept his full share of RESPONSIBILITY. When asked to take charge of a tough job he is not one to complain that he is "all the time being over-worked" or offer the excuse "let George do it." He can be depended on to see that whatever job he is in charge of is done right and—whenever possible—completed on time.

A good leader not only accepts responsibility willingly, but also derives a feeling of satisfaction out of seeing a tough assignment through to completion. This sometimes demands a lot of perseverance—but, even so, a leader is not one to raise the white flag of surrender just because the going gets rough. He is not content merely with turning out a good job, but endeavors to do his work a little better than the next one. He regards the job he is doing as important, not as just a way to earn a day's pay.

To be a strong leader, it is important that you know your job thoroughly. Unless you know more than your men you can not expect them to render the respect due you as leader of their group—and without this respect you will not have the control necessary to efficient production and all-around functioning of your group.

To a large extent, the PO's job often involves supervision and training of lower-rated men. Whether the instruction takes place in the classroom or on the job, you will need to be familiar with various techniques of teaching. Here—as in other jobs where leadership is important—you should be able to inspire, to build confidence, to pass on knowledge, to promote teamwork, and so on. The challenge that faces the Navy supervisor or instructor assumes added significance when you stop to realize that SKILLED LABOR is at the core of SEABEE PROGRESS!

The above discussion does not cover the subject of leadership completely. So broad is that one topic that an entire book could be devoted to it. Use the material here as the starting point to a continuing study on leadership. Also, remember that LEADERSHIP concerns YOU and is going to have a direct bearing on your success as a petty officer.

PRIDE IN SERVICE

There is pride in serving the U. S. Navy!

Your Navy—the greatest Navy in the world today—has a long history of outstanding achievements and noble service. The deeds of your predecessors provide an inspiration and challenge to members of today's Navy, whose job it is to maintain the prestige and traditions of the past.

Pride in the service gives a man respect and admiration for the Navy. It also gives him a sense of BELONGINGNESS. In other words, he feels that he belongs to the Navy; in particular, to the outfit to which he is assigned. This sense of belongingness is of indispensable value because it places special importance on the individual. Regardless of his rank, every man COUNTS and has an important job to do. This makes a man feel responsible to his outfit and to apply himself wholeheartedly to the task of accomplishing its mission. Rather than let his outfit down he is willing to do more than is expected of him, realizing that the mission of his outfit is a one-for-all, all-for-one proposition. It is pride in his outfit that causes a man to strive to make it come out on top in an inspection. He also feels responsible if his outfit fails to make a good showing in such matters as work, drill, or conduct. On the other hand, he shares the enthusiasm of his outfit's recognition for outstanding performance.

Figure 1-2.—Wear it with pride.

Perhaps it is this sense of belongingness we have been talking about that accounts, in large part, for that certain kind of unity or understanding usually found in your social or business contacts with Navy people. Even if you are transferred to a new outfit you will find it easy to make friends with your co-workers and their families. Thus, you have the opportunity in the Navy to form many valuable and lasting friendships.

Not to be overlooked, by any means, is the expression of patriotism on the part of men serving in our Armed Forces. Every service man—from the greenest recruit to the highest ranking admiral or general—should find it satisfying to know he is joined in a common effort to keep our country strong and free. Concerning military service, President Eisenhower has said:

> There is something special about dedicating your lives to the United States of America that lives with you and, what is more important, in my opinion, with your children as long as they shall live.

Bear in mind that pride in the service is an important factor when it comes to maintaining a high level of morale, efficiency, teamwork, and harmony among members of any military organization. It is essential not only to the strength of your battalion or unit, but to the strength of the whole U. S. Navy as well!

REFERENCES

In preparing for advancement it will be to your advantage to supplement your study of this book with material contained in the Navy Training Courses listed in the Reading List at the front of this book. Study carefully the parts of each publication applicable to your rate, as indicated in the Reading List. Reason: Questions on your examination for advancement may be based on material in courses designated in the Reading List, as well as on material in this course.

If you would like to do some additional study on your own, the main object being to learn more about your trade rather than simply to get by on an examination, here are a few publications which will prove useful:

Basic Machines, NavPers 10624, is a good reference on the fundamentals of machinery. Your understanding of the principles of the machinery you will have to maintain, operate, or repair will make a tough job easier.

Mathematics, Vol. 1 and *Vol. 2,* NavPers 10069–A and 10070–A, contain formulas and other information used in computing gallonage, flow, and similar data.

Military Requirements for Petty Officers 3 and 2, NavPers 10056, explains the military duties and responsibilities for the 3 and 2 rates, and is currently a required course for all persons advancing to petty officer status.

Navy publications such as the *Bureau of Ships Manual, Index of Specifications and Standards, U. S. Navy Civil Engineer Corps Bulletin,* and various publications of the Bureau of Yards and Docks will prove helpful as sources of technical information.

Department of the Army technical manuals (TM's) and technical bulletins (TB's), as well as maintenance manuals and pamphlets issued by manufacturers of tools and equipment will provide useful references on the construction and operation of equipment.

Ask your training officer how to obtain any of these publications not readily available. He will not only help you to get the material you need but will also help you to prepare for your advancement in rating. Of course, he can only go so far—the rest is up to you. What it boils down to is this: the opportunity for advancement is there, but it is up to the individual concerned whether he takes advantage of it or not.

Remember that as a Utilities Man you will be doing an important job. Whether you are assigned to the public works department of a base, a mobile construction battalion, an amphibious construction battalion, or other Seabee-type activity, the work you do will be important in the maintenance and operation of the base utilities.

QUIZ

1. What are the "utilities" of a naval base?
2. In what rating group is Utilities Man included?
3. What are practical factors?
4. What are examination subjects?
5. When were the Seabees officially established?
6. What Bureau exercises technical control over the organization, equipment, and operational procedures of the Seabees?
7. Name the five companies which usually compose the basic military organization of a mobile construction battalion.
8. What would you recommend as a good way for the PO to get to know his men?
9. From whom can you obtain publications needed to supplement this course?

CHAPTER 2

PLUMBING

PLUMBING is the art of installing in buildings the pipes, fixtures, and other apparatus for bringing in the water supply and removing the liquid and water-carried wastes. When properly installed and maintained, a plumbing system is more than just a convenience. It is also an aid to good health and sanitation.

To become a good plumber you will have to acquire a lot of information—information on piping materials, fittings, tools, methods, and procedures used in plumbing work. You will also need a lot of on-the-job training under a good supervisor or instructor—training that will enable you to develop skill in using the tools of this trade, as well as to acquire efficiency in carrying out a job according to the methods and procedures considered as standard practice in plumbing.

This chapter deals primarily with such topics as pipe materials, fittings, and duties having to do with the INSTALLATION of a plumbing system. The following chapter discusses various REPAIRS AND ADJUSTMENTS which you may be called on to make in existing plumbing systems. You will not find everything you need to know to become a master plumber. However, by studying carefully the material in this chapter and chapter 3, then putting into practice what you learn, you should be well on your way toward developing the basic skills of this trade.

TYPES OF PIPE

Various types of pipe are presently used in plumbing. It will be to your advantage to know where to use each of the common types that will concern you in your work. Pipe used in the installation of a plumbing system may be broken down into two groups: belowground pipe and aboveground pipe.

For sewers and drains, which make up that part of the plumbing system installed BELOWGROUND, four principal kinds of pipe are used: cast iron, acid-resistant cast iron, clay, and asbestos cement.

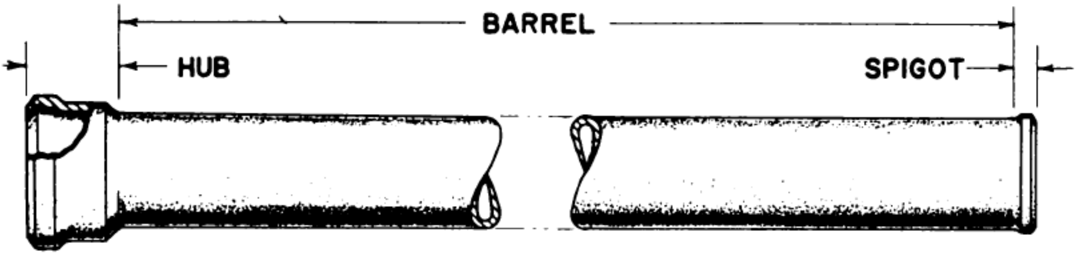
For soil waste and vent installation, which form that part of the plumbing system ABOVEGROUND, the following types of pipe are suitable: cast iron, galvanized steel and galvanized wrought iron, copper, brass, lead, and acid-resistant cast iron.

Belowground Pipe

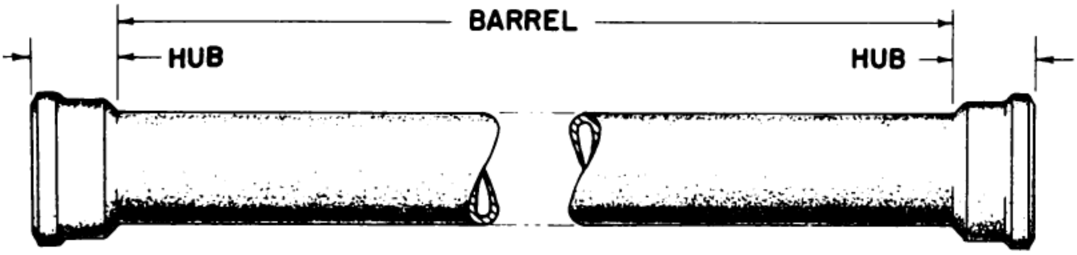
CAST-IRON PIPE is used in plumbing drains and sewer installations. There are two types of cast-iron pipe. They are the BELL AND SPIGOT type and SOIL PIPE.

Bell and spigot cast-iron pipe may be used for water pressures up to 150 psi. It is manufactured in 4- and 6-inch diameters, and is available in 12 and 16 foot lengths. Each length is coated inside and out with a smooth coal tar pitch varnish.

SOIL PIPE is similar in appearance to bell and spigot pipe, but it is not designed to withstand pressures greater than 10 psi. Cast-iron soil pipe comes in 5 foot lengths of 3-, 4-, 5-, and 6-inch nominal inside diameters. It is available as single-hub or double-hub in design, as indicated in figure 2–1. Note that single-hub pipe has a hub at one end and a spigot at the other, while double-hub pipe has a hub at both ends. Hubs and bells of cast-iron pipe are enlarged, sleeve-like fittings which are cast as a part of the pipe and are utilized to make a water- and pressure-tight joint with packing and lead.



SINGLE HUB PIPE



DOUBLE HUB PIPE

Figure 2–1.—Single-hub and double-hub cast-iron soil pipe.

Cast-iron soil pipe is gradually replacing vitrified clay pipe, which can also be used for sewer lines. Where you have unstable ground it will be to your advantage to use cast-iron soil pipe. However, cast-iron soil pipe should not be used in soil containing cinders or ashes. That is because the soil may contain sulphuric acids, which would cause the pipe to corrode.

VITRIFIED CLAY PIPE is commonly used for storm, as well as sanitary, sewer lines. It comes in lengths of 2 feet 6 inches and has a bell-and-spigot end to permit joining. It has resistance to most acids. But if laid in unstable soil, vitrified clay pipe will sag and crack. Make sure that the trench in which a vitrified clay pipeline is to be laid IS NOT more than one foot wider than the pipe for sizes larger than 12 inches, and not less than two feet wide for smaller sizes, when pipe is to be jointed in the trench. In backfilling the trench you will have to exercise care to see that the pipe is first covered with rock and stone, fill dirt, or sand. The risk of clogging the sewer line is greater with vitrified clay pipe than with cast-iron soil pipe. In connection with clogging, bear in mind that tree roots will grow right through the joints of clay pipe and stop up the line.

ASBESTOS-CEMENT PIPE (where available) may be used for sewer lines where conditions are suitable. It comes in standard lengths of 13 feet; half-lengths are also available. This pipe is light in weight and easy to handle. Asbestos-cement pipe is also corrosion-resistant and will not rust or rot. Adaptors are available for connecting asbestos-cement pipe to pipe made of other materials.

Aboveground Pipe

GALVANIZED STEEL PIPE is the most commonly used type of pipe found in aboveground plumbing. It is made of mild steel and comes in 20 foot lengths. At the factory, galvanized steel pipe is dipped in zinc to provide protection against acids.

While GALVANIZED WROUGHT-IRON PIPE is an excellent material for aboveground plumbing, a big drawback to its use lies in its cost, which is about twice that of galvanized steel. Galvanized wrought-iron pipe is constructed of wrought iron dipped in molten zinc. It is, of course, more resistant to acid waste than non-galvanized steel.

Acid-resistant cast iron pipe is composed of an alloy of cast iron and silicon. It is used to serve chemical laboratories and other installations through which waste of an acid nature flows. In handling acid-resistant pipe such as Durion, you will need to exercise care because it is very brittle and cracks easily. It is cast in 5 foot lengths, and comes in single and double hubs.

BRASS PIPE, another aboveground plumbing material, consists of an alloy of zinc and copper. It is very suitable for use on ships because of its high resistance to salt water. Brass pipe has a smooth interior and can resist most acids; however, it is expensive to use. It is available in 20 foot lengths, and because of its tendency to bend it must be supported at intervals of 8 to 10 feet.

Lead or lead-lined steel pipe is sometimes used to carry distilled water for batteries. However, tin-lined, block tin, glass or some types of plastic pipe must be used where no impurities are acceptable. Because lead bends easily, lead pipe must be well supported. It is available in three weights: (1) standard, (2) common, and (3) extra heavy. The standard weight is commonly used.

COPPER PIPE is suitable for use in waste, vent, and water installations. One point to remember is that ammonia affects copper lines. Also, when copper tubing is used for the purpose of waste pipe installations, always make sure it is rigid. This is necessary to overcome sagging. You can obtain the pipe in convenient lengths, then cut it to the size needed for the job at hand.

FITTINGS

The term FITTINGS refers to the parts and materials of the piping system used to provide bends in pipelines, branches, and connections; to seal pipes; and to attach fixtures.

Figure 2–2 shows you some of the common fittings used in plumbing. Familiarize yourself with the design and purpose of each type illustrated.

TEES are easy to recognize, being three-way devices which are shaped, ordinarily, like the letter "T." Use tees when it is necessary to connect branches to continuous lines. For connecting lines of different sizes, use REDUCING tees. Where a side outlet is needed, select a SIDE OUTLET tee.

Y-BRANCHES, as the name implies, are shaped like the letter "Y." Their purpose in plumbing is to take a 45° or 60° line from a run of pipe.

A CROSS is the fitting employed to connect intersecting lines. It has four openings arranged at 90° angles to each other, and in appearance resembles a plus sign.

ELBOWS, also called ELLS, provide the means for making

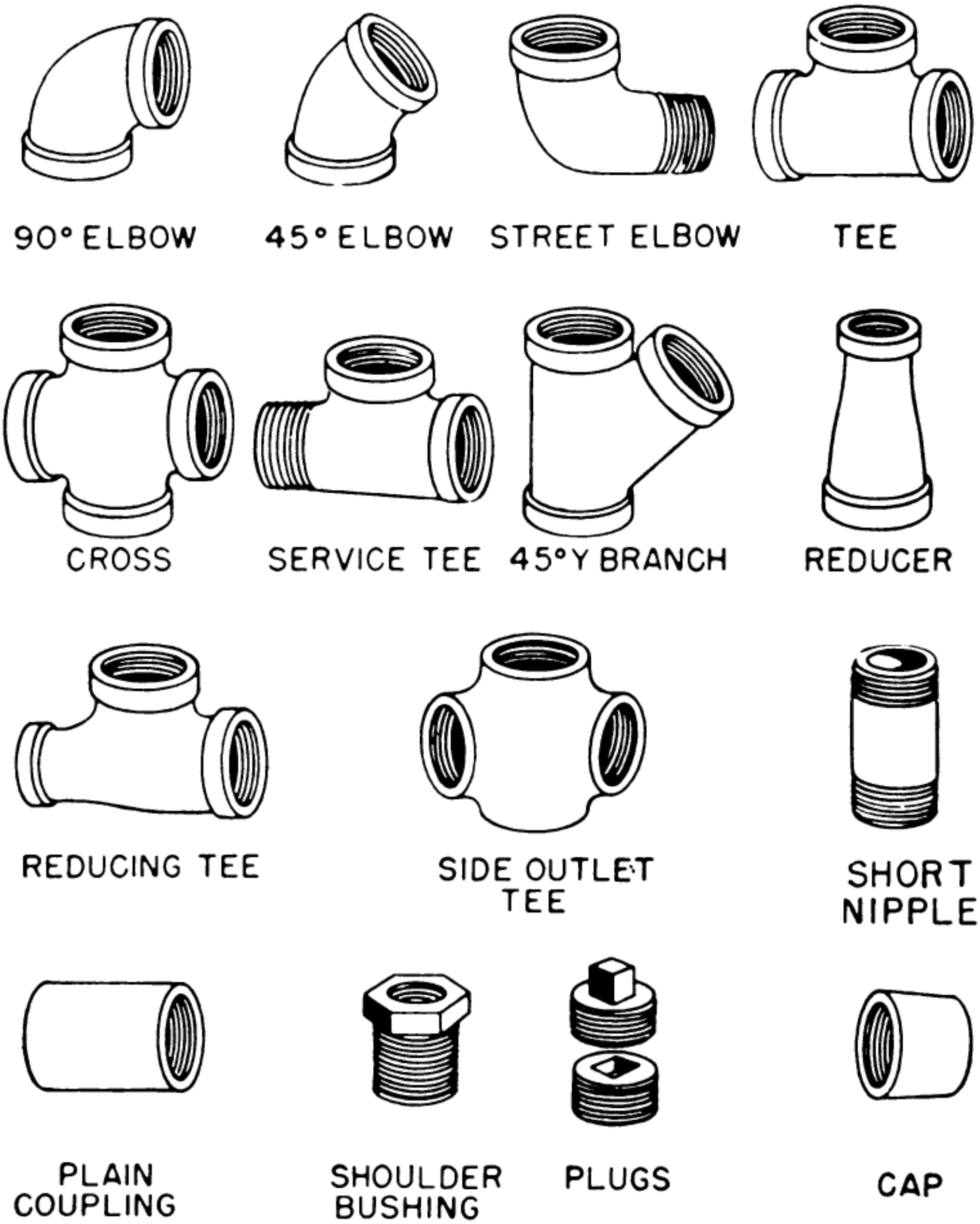


Figure 2–2.—Pipe fittings.

turns in the piping line. There are other degrees of turn as well as the 90° and 45° elbows shown in figure 2–2.

A STREET ELBOW (also referred to as a STREET ELL) has one female thread and one male thread. This fitting provides a means for changing the direction of an iron pipeline in a close space where it would be impossible or impracticable to use an elbow or nipple. A 45° and a 90° style of street elbow are available.

BUSHINGS are devices which can be screwed into the end of fittings or valves to decrease the size of the end opening.

PLUGS are used to close the end of a pipe which has inside threads. In the case of outside threads, a CAP, rather than a plug, is used.

A COUPLING is a device used to connect straight sections of pipe. REDUCERS are employed to join two sections of pipe which are different in size.

NIPPLES are short pieces of threaded pipe, up to 12 inches in length, which are used to connect two other parts together. One type, known as the SHORT NIPPLE, is shown in figure 2–2. Notice that it is threaded at each end. Other types include the close nipple and the long nipple. The CLOSE NIPPLE is threaded its entire length and is used where a close connection is needed between parts. The LONG NIPPLE includes any pipe up to 12 inches in length which is threaded at each end.

HAND TOOLS

Plumbers use quite a variety of hand tools, and one thing to look for in determining the proficiency of a plumber is the degree of skill he exercises in using the tools of his trade. Let us discuss briefly some of the hand tools commonly used in the installation of a plumbing system. You should be familiar already with various elementary plumbing tools if you have studied *Basic Hand Tool Skills,* NavPers 10085. Don't fail to study this book for additional information in case you feel the need for brushing up on the subject of tools.

Wrenches

A number of different types of wrenches are used in plumbing, several of which are illustrated in figure 2–3. The PIPE WRENCH, of course, is used on pipe. Its jaws are provided with teeth which grip the pipe when pressure is applied to the handle. Pipe or stillson wrenches are available in a number of sizes (lengths). The size selected

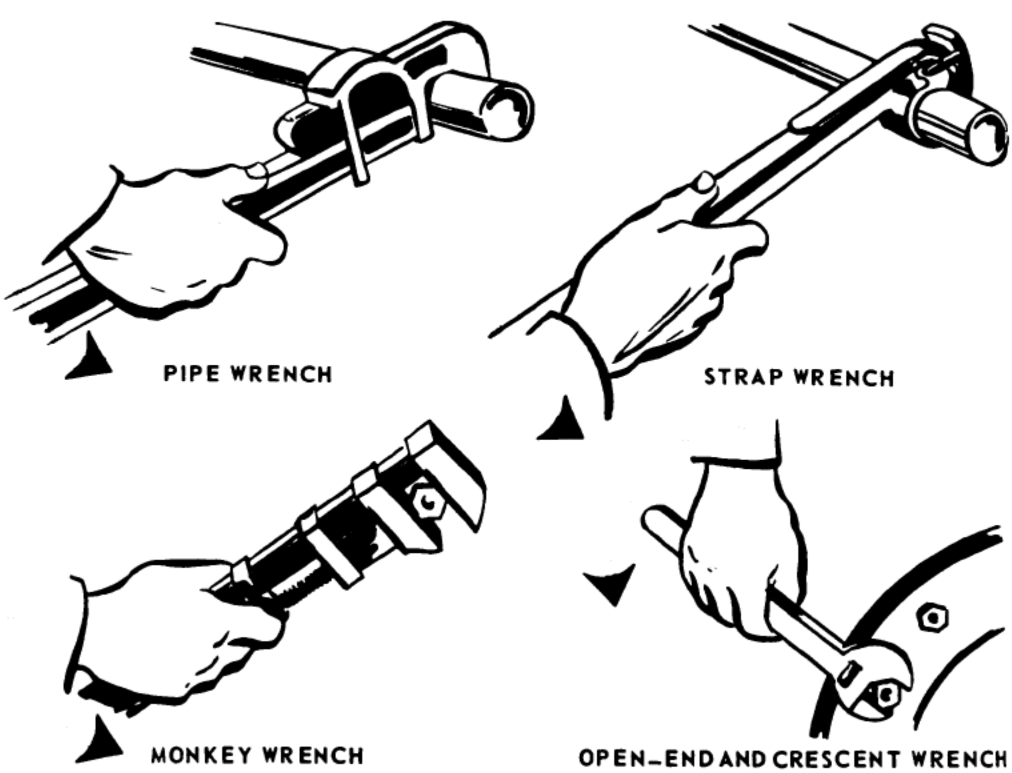


Figure 2–3.—Wrenches. (A) Pipe wrench. (B) Monkey wrench. (C) Adjustable open-end wrench. (D) Strap wrench.

should depend on the size of the pipe—for instance, a 6-inch size wrench on $\frac{1}{8}$- to $\frac{1}{4}$-inch pipe and a 10-inch size on $\frac{1}{2}$-inch pipe.

The MONKEY WRENCH is the tool to select for hexagonal nuts, valves, and fittings. Its smooth jaws can be fitted well on flat-sided bolts or fixtures, and it does not have the crushing effect of the pipe wrench.

An ADJUSTABLE OPEN-END WRENCH is suitable for tightening nuts and bolts. However, it has a tendency to round off the corners of hex nuts unless the jaws are closely adjusted to fit the work.

The STRAP WRENCH works better than the pipe wrench in cramped spaces. It should also be used on plated or polished pipe to avoid marring the pipe surface.

Measuring Tools

The spirit level and plumb bob are two important tools which the plumber uses in making measurements. The

SPIRIT LEVEL is used to level and plumb pipes for vertical alinement. The PLUMB BOB is a handy device for locating holes in the floor and ceiling. Other tools in this category include the square, folding rules, and steel tapes.

Pipe Cutting Tools

Hand pipe cutters can be used satisfactorily for cutting pipe, conduit, and tubing up to 4½ inches in diameter. Two types of hand cutters commonly in use are: wheel-and-roll cutters and three-wheel cutters.

The WHEEL-AND-ROLL CUTTER, shown in figure 2–4, must be revolved completely around the pipe. It is used

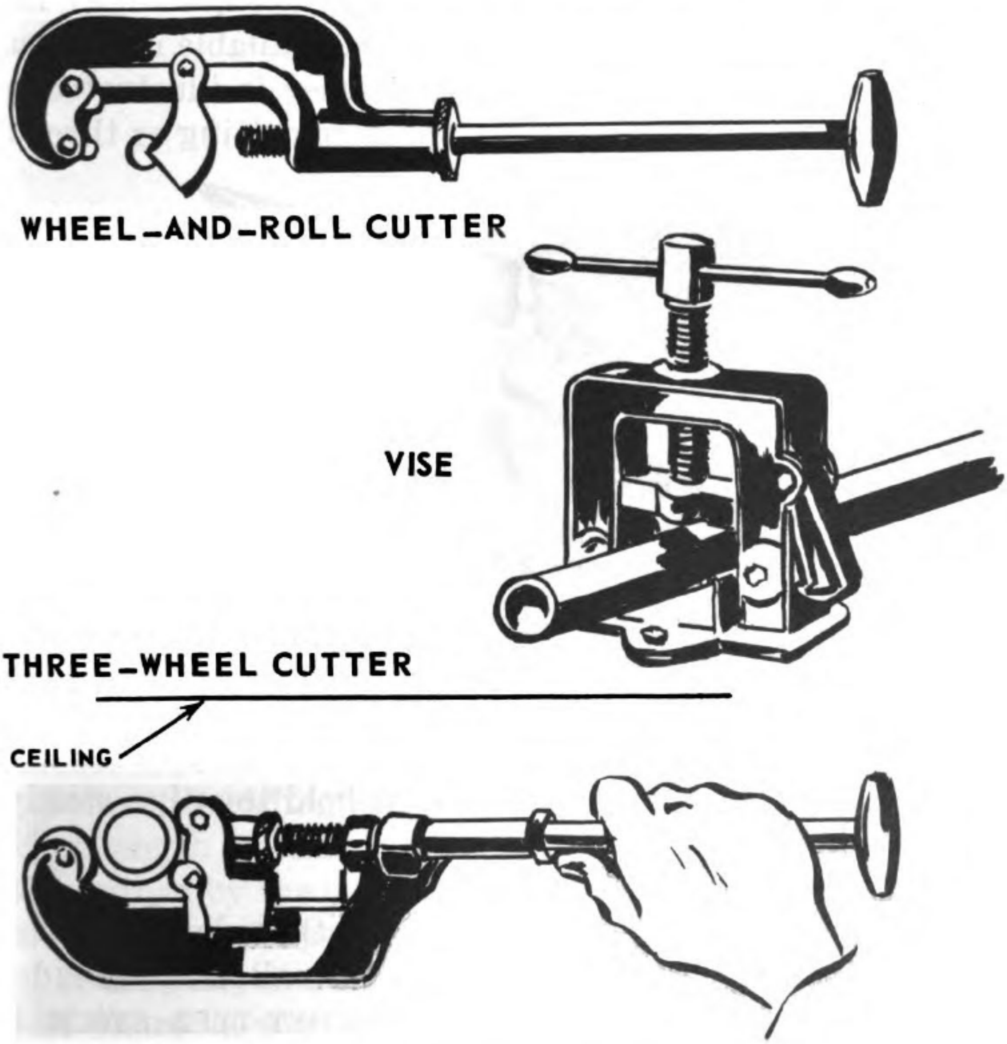


Figure 2–4.—Pipe cutting tools.

in combination with a pipe vise (fig. 2–4), which exerts a uniform four-way pressure on the pipe and holds it steady.

The THREE-WHEEL CUTTER (see fig. 2–4) is used when it is impossible to make a full turn with the wheel-and-roll cutter, as in overhead pipework. An advantage of the three-wheel cutter is that one-half turn of the cutter makes a complete cut around the pipe, whereas, with the wheel-and-roll cutter a full turn is required.

Reamer

A reamer should be used after a pipe has been either cut or threaded to remove the burr (or rough edge) left on the inside of the pipe. Reamers are available in various types and sizes. A common type reamer is illustrated in figure 2–5. If the burr that results from cutting or threading is not removed, it will restrict the flow of fluid in the pipe. Too, it may very well result in accumulation of foreign matter and cause the line to choke up. Besides a reamer, you will also need a vise to hold the pipe steady.

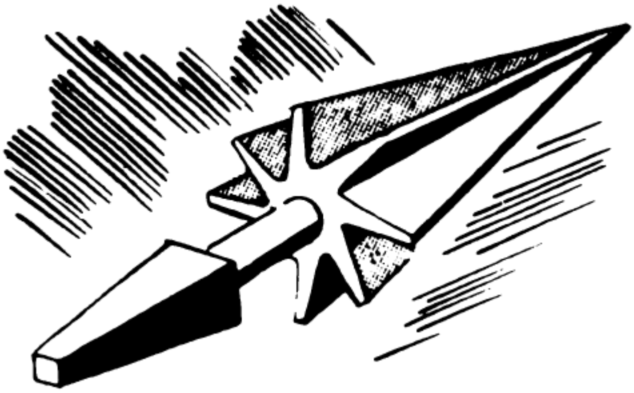
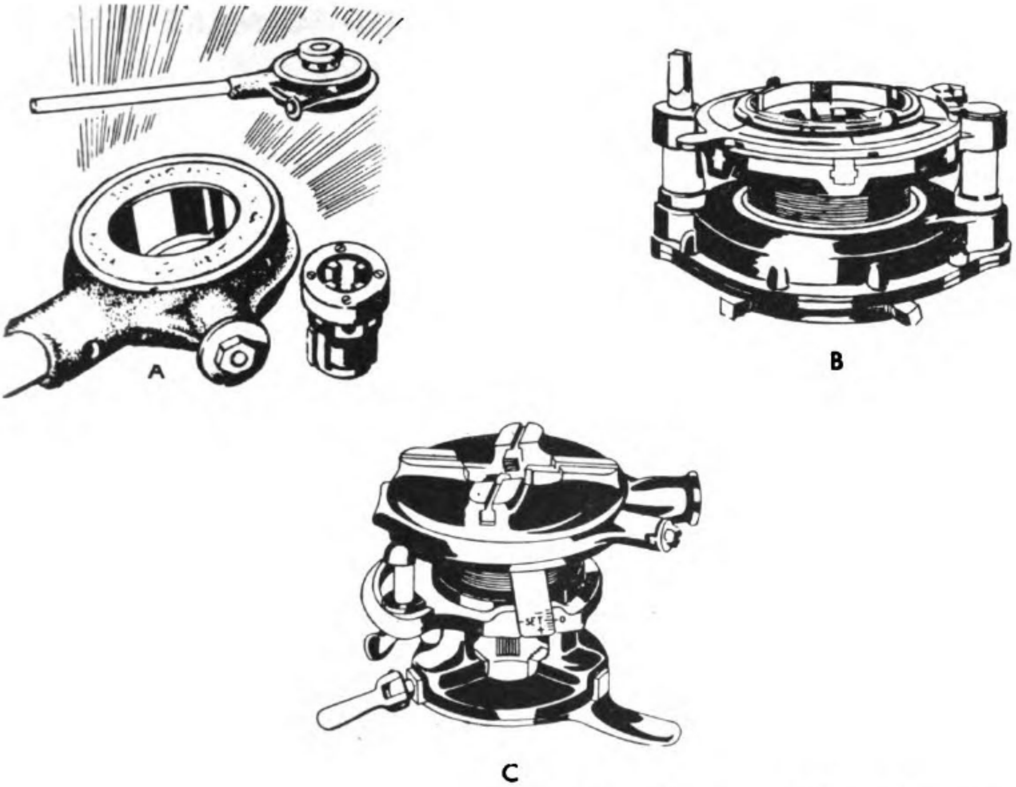


Figure 2–5.—Reamer.

Threading Tools

In the Seabees, three types of pipe threaders are commonly used to thread pipe by hand. A small hand threader having REMOVABLE DIES AND A RATCHET-TYPE STOCK is the tool you will need to thread ⅛- to 1-inch pipe. This type is illustrated in part A, figure 2–6.



Courtesy of Theo. Audel and Company

Figure 2–6.—Hand pipe threaders. (A) Stock and die threader. (B) Geared-type threader. (C) Ratchet-type threader.

A second type is the GEARED threader, which has adjustable die cutters. It is used for threading 2½- to 6-inch pipe. Part B, figure 2–6 shows you what this type is like.

A third type of threader is the RATCHET type illustrated in part C, figure 2–6. This threader is used to thread 1- to 2-inch pipe. It has a die with adjustable cutters and a ratchet-type stock.

Before threading a piece of pipe you will need to know what length to make the thread cut. The length will be determined by the size (in inches) of the pipe. Dimension *A* in figure 2–7 specifies the length of thread required to make a tight joint on various sizes of pipe.

If there is any question about a thread being long enough, remember that the thread is long enough when one or two threads are visible beyond the die segments.

LENGTH OF THREAD ON PIPE REQUIRED TO MAKE A TIGHT JOINT

SIZE OF PIPE, INCHES	DIMENSION *A*, INCHES	SIZE OF PIPE, INCHES	DIMENSION *A*, INCHES	SIZE OF PIPE, INCHES	DIMENSION *A*, INCHES
1/8	1/4	1 1/2	11/16	5	1 1/4
1/4	3/8	2	3/4	6	1 5/16
3/8	3/8	2 1/2	15/16	7	1 3/8
1/2	1/2	3	1	8	1 7/16
3/4	9/16	3 1/2	1 1/16	9	1 1/2
1	11/16	4	1 1/8	10	1 5/8
1 1/4	11/16	4 1/2	1 3/16	12	1 3/4

Figure 2–7.—Length of thread on pipe required to make a tight joint.

Copper Pipe Bending Tools

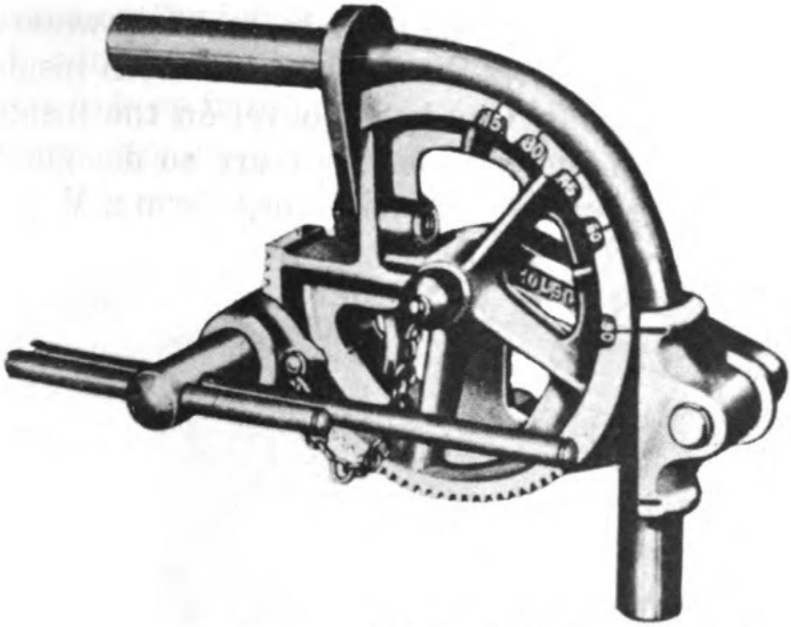
You can bend a small copper pipe by hand without the aid of a bending device. However, bending tools will help you do a better and quicker job.

One of the tools used in bending copper pipe is a spring-tube bender, which helps keep the pipe from collapsing while bending it to any angle. Other devices include the portable pipe bender shown in figure 2–8. This tool can be bolted to a bench or pipe vise.

Calking Tools and Lead Melting Equipment

Calking tools which are used in making lead joints on cast-iron soil pipe include the yarning iron, joint runner, and calking iron illustrated in figure 2–9.

The YARNING IRON is used to yarn (or tamp) oakum in the joint previous to pouring in the molten lead. A hammer will also come in handy as it can be used to strike the yarning iron and drive the oakum in place. One characteristic to remember about oakum is that when wet it will swell and form a watertight joint seal. Rubber ring, asbestos rope, or paper gaskets are required in lieu of oakum on potable water lines.



Courtesy of Copper and Brass Research Association

Figure 2-8.—Portable pipe bender.

The JOINT RUNNER (or POURING ROPE) is used to pour horizontal, upside down, or inverted joints. Before the lead is poured into the joint, the runner must be clamped around the pipe and fastened in place with a clamp.

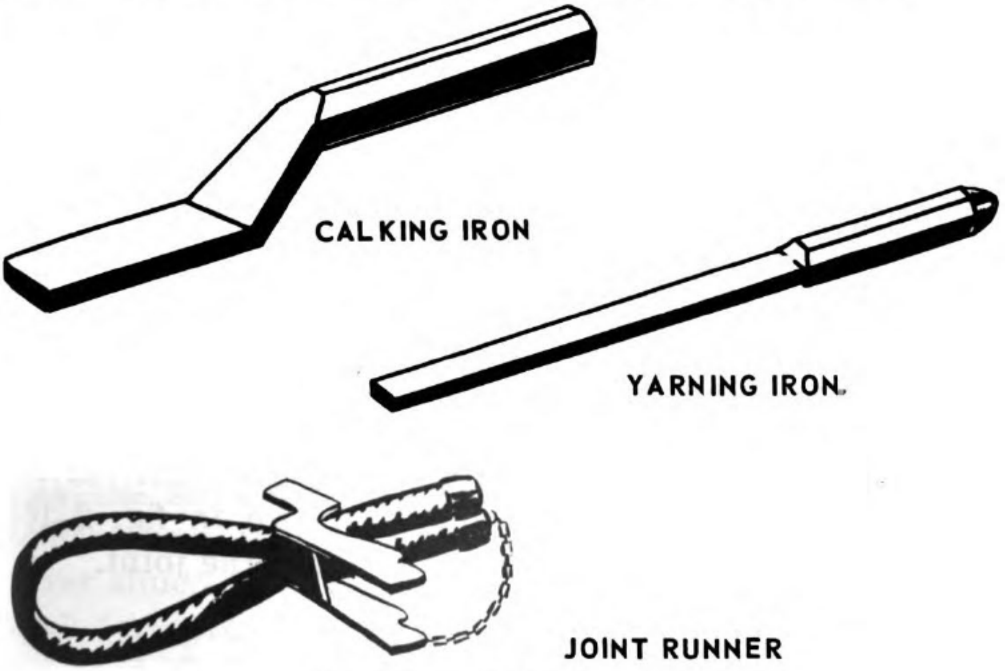


Figure 2-9.—Calking tools.

To calk lead around the joint to make it watertight, you will need a CALKING IRON. There are both inside and outside calking irons. One has a bevel on the inside, the other, a bevel on the outside. They are so designed that when the two are put side by side they form a V.

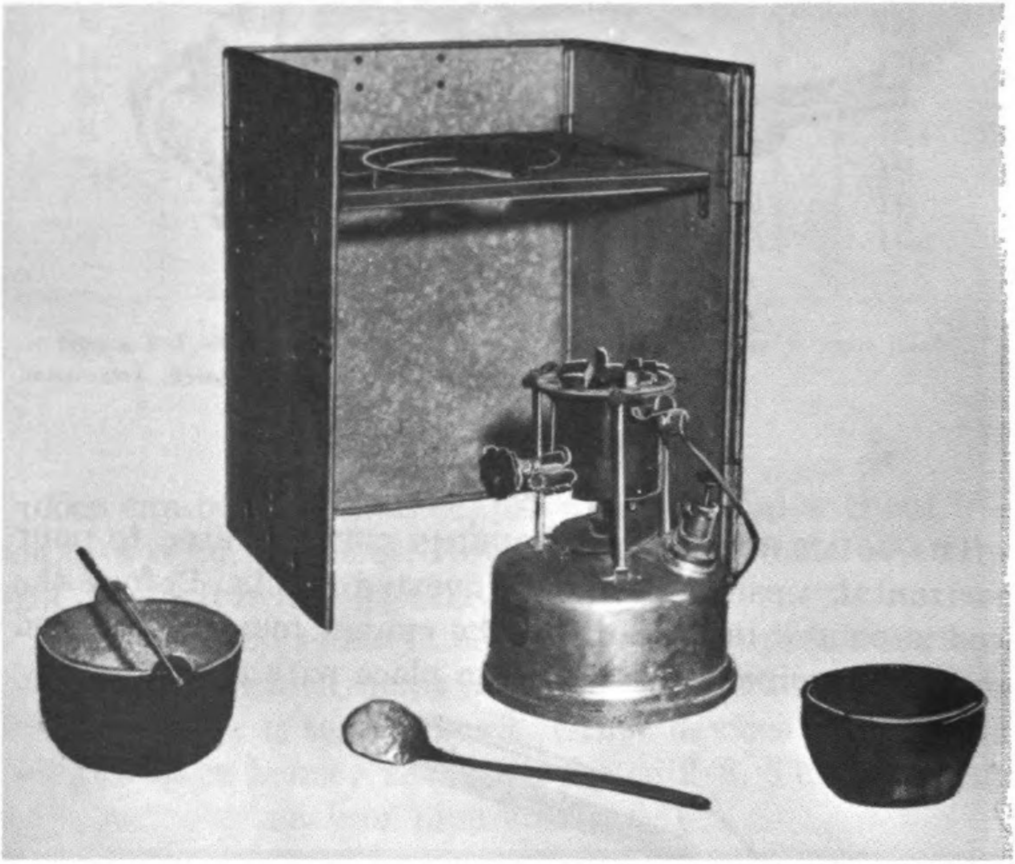


Figure 2–10.—Plumber's furnace and accessory equipment.

Figure 2–10 shows you the plumber's furnace (or fire pot) and accessory equipment used in melting the lead to be poured into the joint. The lead is melted in the pot on the left in the illustration. During the melting operation this pot sits in the container on the right in the illustration. A pouring ladle (also shown in fig. 2–10) is the device used to pour the hot lead into the joint.

Care of Tools

To prolong the life of tools and have them perform efficiently on the job, it is important that they receive the proper care and upkeep. On this score, here are a few pointers to keep in mind:

—Never use defective tools.

—As an aid to rust-prevention, clean tools as often as needed with a Navy-approved solvent.

—Besides keeping wrenches sharp and clean, make sure that the springs are active and unbroken and that pins are tight. Also, use wrenches that fit the task at hand. An extension should NEVER be used on a wrench.

—See that the head of a hammer is wedged securely and squarely on the handle, and that neither the head nor the handle is chipped or broken. Also, keep the hammer clean and free from oil or grease which might cause the handle to slip from the hands, or cause the face of the hammer to glance from an object being struck.

—Keep all loose tools off the floor to prevent trips or falls.

—Do not carry tools in your pockets or pants belt—especially edged or pointed tools.

—Check the condition of tools before you use them. If any are found defective, see that they are repaired or turned in right away.

—Keep tools in their proper places when not in use.

CUTTING PIPE

The wheel-and-roll cutter (fig. 2–4) is a simple tool to use when you follow a few simple instructions. Start by selecting the proper size cutter for the pipe to be cut. Then measure and mark the pipe and tighten it in a vise, with the section to be cut extending beyond the vise. Loosen the cutter wheel by turning the handle until the cutter slides over the pipe. Place the cutter wheel at the mark for cutting and tighten the handle until the wheel is forced slightly into the pipe. Now revolve the cutter all the way around the pipe. Next, turn the handle one-quarter turn and revolve the cutter around the pipe a second time. Repeat this operation until the pipe is cut.

When using the three-wheel cutter, follow this procedure: Place the three cutter wheels on the mark for cutting and revolve the cutter halfway around the pipe (see fig. 2–11A). Tighten the cutter wheel by turning the

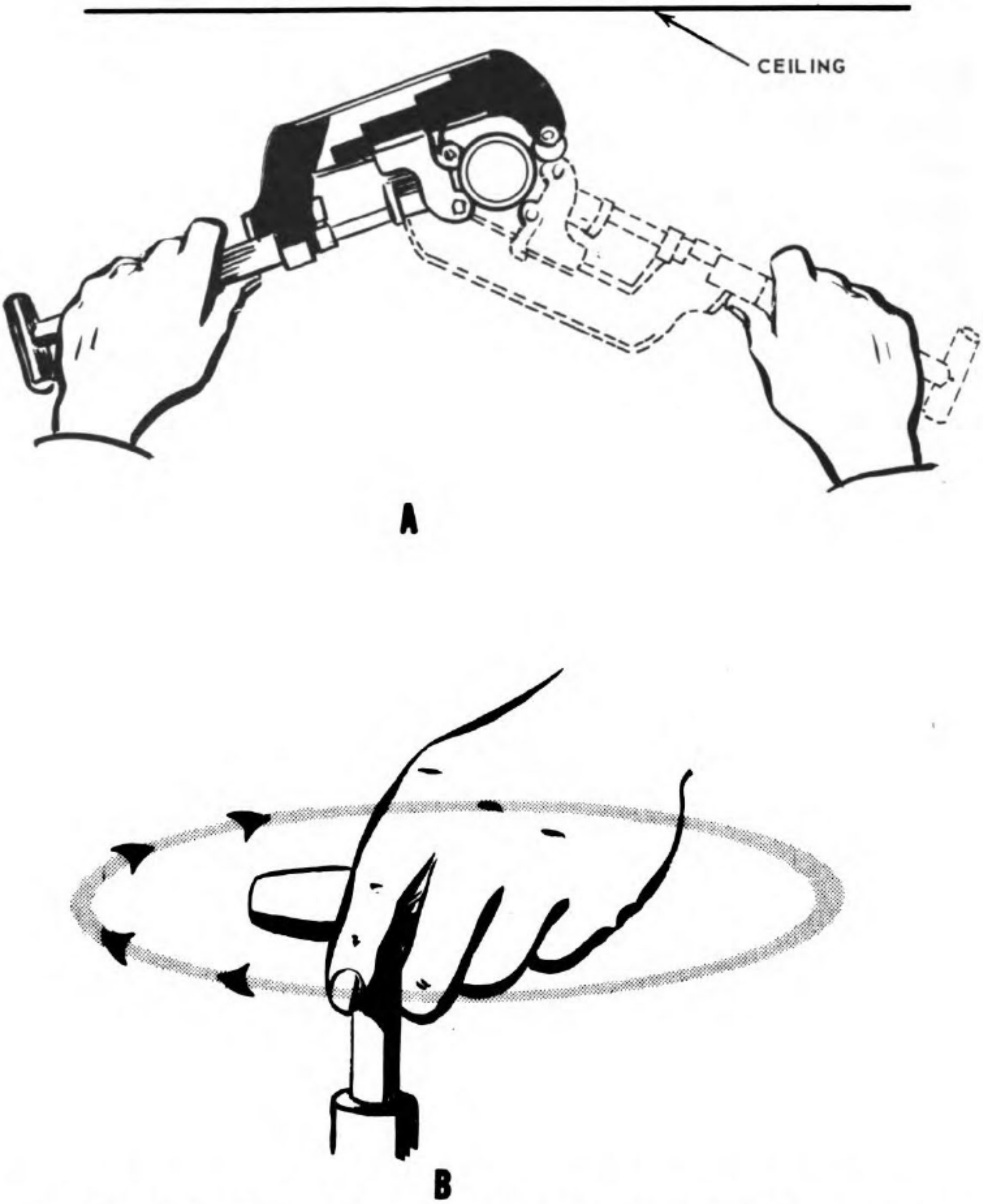


Figure 2–11.—Using three-wheel cutter. (A) Revolve cutter halfway around pipe. (B) Turn handle one-quarter turn.

handle one-quarter turn and revolve the cutter around the pipe back to the starting point (see fig. 2–11B). Again move the handle one-quarter turn and revolve the cutter halfway around the pipe.

REAMING

Before starting the reaming operation on a piece of pipe that has been cut, make sure the reamer is held firmly in the vise. With that done, insert the tip of the reamer in the pipe and turn the handle. When you apply pressure, do so steadily. Remember to clean the reamer frequently, using a brush with stiff bristles, if available, to keep small bits of metal out of the pipe opening.

When a three-wheel cutter is used, the outside edge of the pipe will also be burred. A file can be used to dress down these rough edges.

THREADING PIPE

If the threading is to be done with the small STOCK-AND-DIE threader (fig. 2–6), here's how to do it. First place the correct size die in the stock. Then place the pipe to be threaded in a vise so that the end to be threaded projects beyond the bench. Now slide the stock over the pipe until the pipe strikes the die. Next, turn the stock with one hand, holding it firmly against the pipe until the die starts to cut. After two or three turns this forward pressure will not be needed. During the turning operation, make sure you keep the handle of the stock at right angles to the pipe, else your threads will come out crooked.

You will need, during the cutting operation, to apply a thread-cutting oil to the thread, die, and pipe every two or three turns. The oil will reduce wear and tear on the pipe threader.

If using the RATCHET-TYPE threader (fig. 2–6), start by adjusting the thread cutters to the correct diameter. Then place the cutter on the pipe and proceed by turning the ratchet handle as described above for the small stock-and-die cutter.

To cut threads with the GEARED-TYPE pipe threader (fig. 2–6), adjust the thread cutters to the size of the pipe. Then insert the proper size sleeve in the threader, and after positioning the threader on the pipe, tighten the set screws to hold the sleeve in place. With that done, install the ratchet handle on the threader and cut the threads.

Power Threading

To obtain a maximum of precision in your threading always use a power machine—where one is available. Take a close look at the power threader shown in figure 2–12. For cutting threads on this machine follow the procedure below, in the order given:

—Place the pipe to be threaded in the chuck and tighten.

—Replace the chuck wrench in the holder.

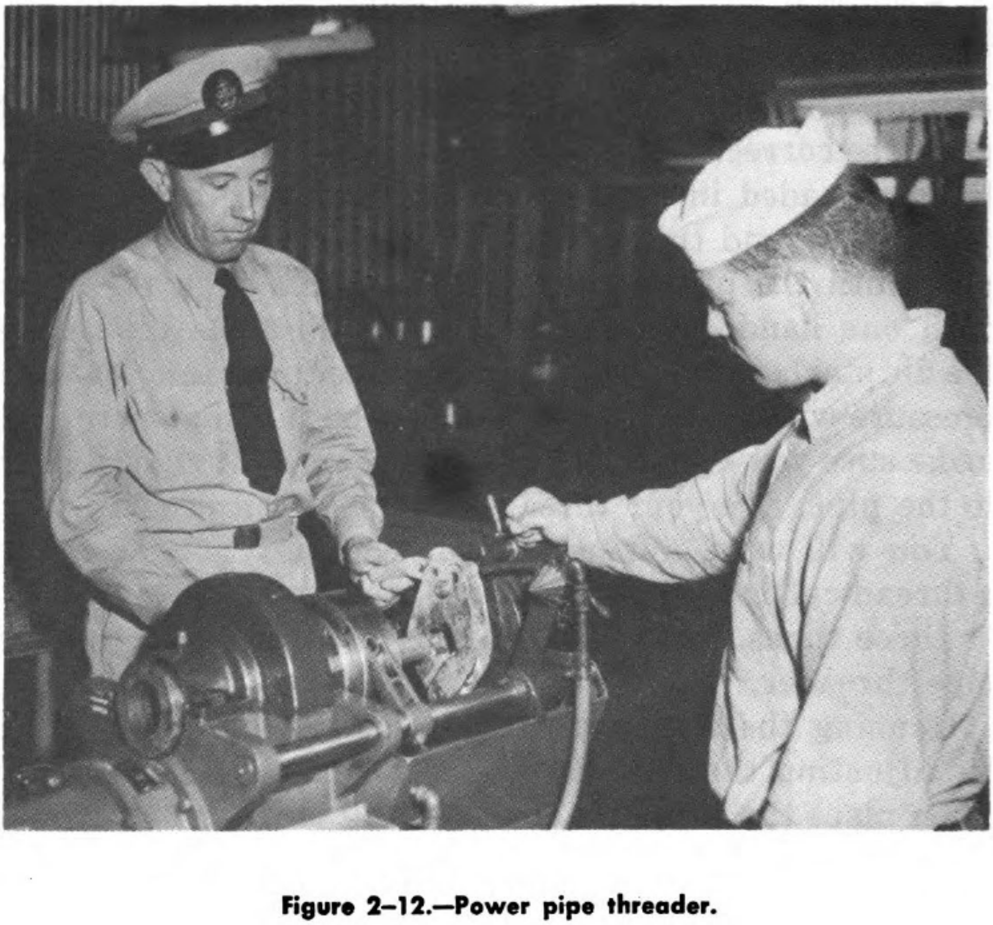


Figure 2–12.—Power pipe threader.

—Select the proper size dies and adjust them.
—Turn on the switch.
—Move the carriage to place the dies in position.
—Thread the pipe to proper length.
—Shut off the machine.
—Check the threads with the fitting.

BENDING COPPER PIPE

Sometimes it is necessary or desirable to bend copper pipe or tubing. It is easier and cheaper to make bends than to install fittings, and they are less likely to leak or clog. A hot bending method is used for large-diameter and heavy-walled pipes. A cold bending method is commonly used for pipes under 4 inches in diameter, thin-walled pipe, and coils. The method selected depends on the job to be done and the equipment available. Bending devices include the spring-tube bender and portable pipe bender (refer back to fig. 2–8).

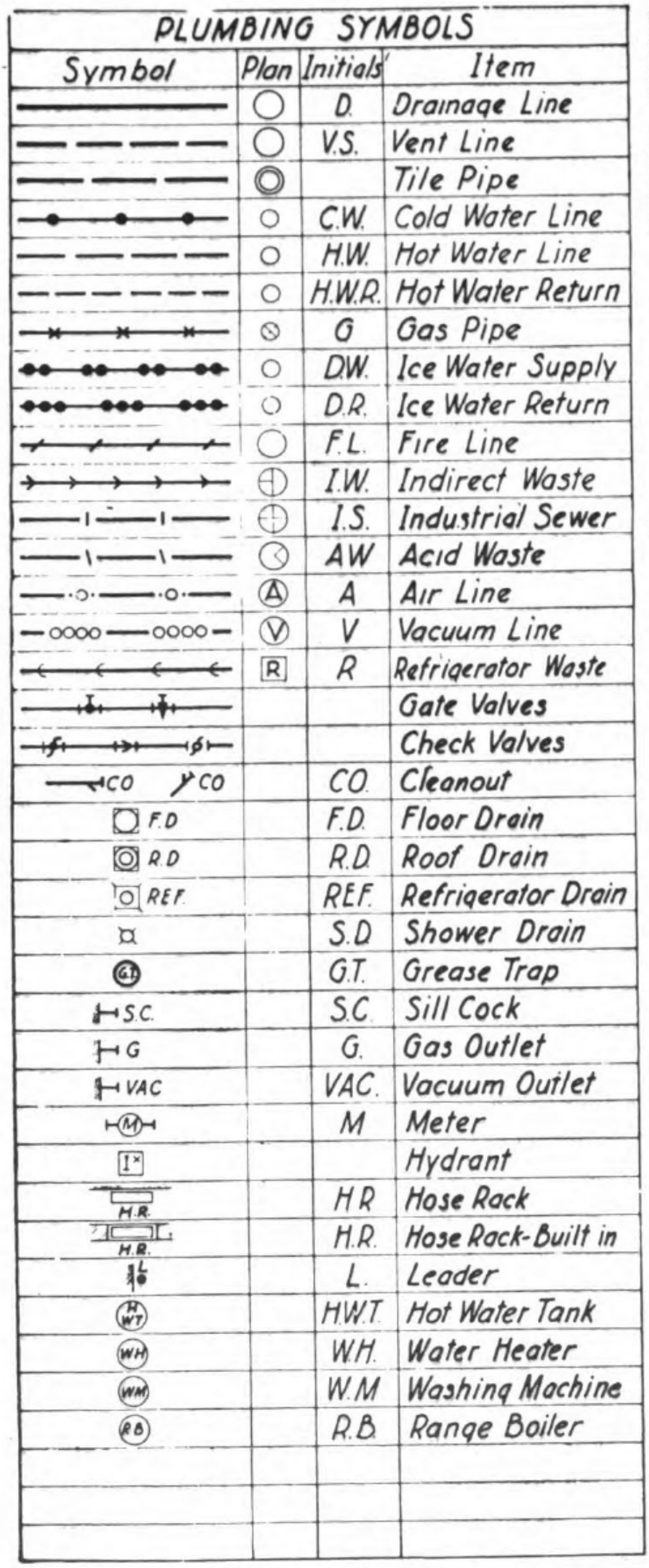
Before bending, pipes should be filled to keep them from flattening or collapsing at the bend. Sand is the filler material commonly used.

A torch is used to heat the part of the pipe being bent by the hot bend method. Wooden or wire templates may be used as patterns for the bends.

ROUGHING-IN

The term ROUGHING-IN refers to the water supply and waste pipes which make up that part of the plumbing system usually concealed in the walls and floors, and usually installed while the building is being framed. Since fixtures are not installed in roughing-in, see that fixture and clean-out, as well as drain and lateral openings are capped or plugged. Purpose of this precaution is to prevent dirt and refuse from entering the system and causing stoppages later.

Roughing-in plans for a building are usually drawn up



PLUMBING SYMBOLS			
Symbol	Plan	Initials	Item
	○	D.	Drainage Line
	○	V.S.	Vent Line
	◎		Tile Pipe
	○	C.W.	Cold Water Line
	○	H.W.	Hot Water Line
	○	H.W.R.	Hot Water Return
	⊘	G	Gas Pipe
	○	D.W.	Ice Water Supply
	○	D.R.	Ice Water Return
	○	F.L.	Fire Line
	⊕	I.W.	Indirect Waste
	⊕	I.S.	Industrial Sewer
	○	AW	Acid Waste
	Ⓐ	A	Air Line
	Ⓥ	V	Vacuum Line
	R	R	Refrigerator Waste
			Gate Valves
			Check Valves
CO CO		CO.	Cleanout
F.D		F.D.	Floor Drain
R.D		R.D	Roof Drain
REF.		REF.	Refrigerator Drain
		S.D	Shower Drain
G.T.		G.T.	Grease Trap
S.C.		S.C.	Sill Cock
G		G.	Gas Outlet
VAC		VAC.	Vacuum Outlet
M		M	Meter
I×			Hydrant
H.R.		H.R.	Hose Rack
H.R.		H.R.	Hose Rack-Built in
L		L.	Leader
H WT		H.W.T.	Hot Water Tank
WH		W.H.	Water Heater
WM		W.M.	Washing Machine
RB		R.B.	Range Boiler

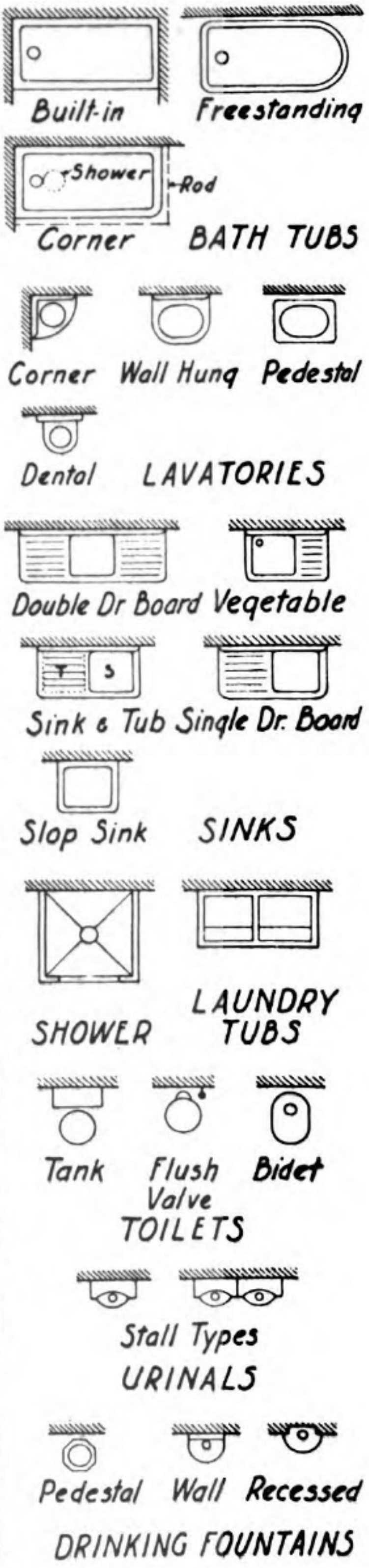


Figure 2-13.—Plumbing symbols.

by an architect. It is important that you follow specifications on roughing-in plans which concern the location of pipes, types and sizes of materials, and outlets for fixtures.

In performing roughing-in duties you may often find symbols used to designate pipes, fittings, or fixtures, so familiarize yourself with the symbols shown in figure 2–13.

GLOBE, ANGLE, GATE AND CHECK VALVES

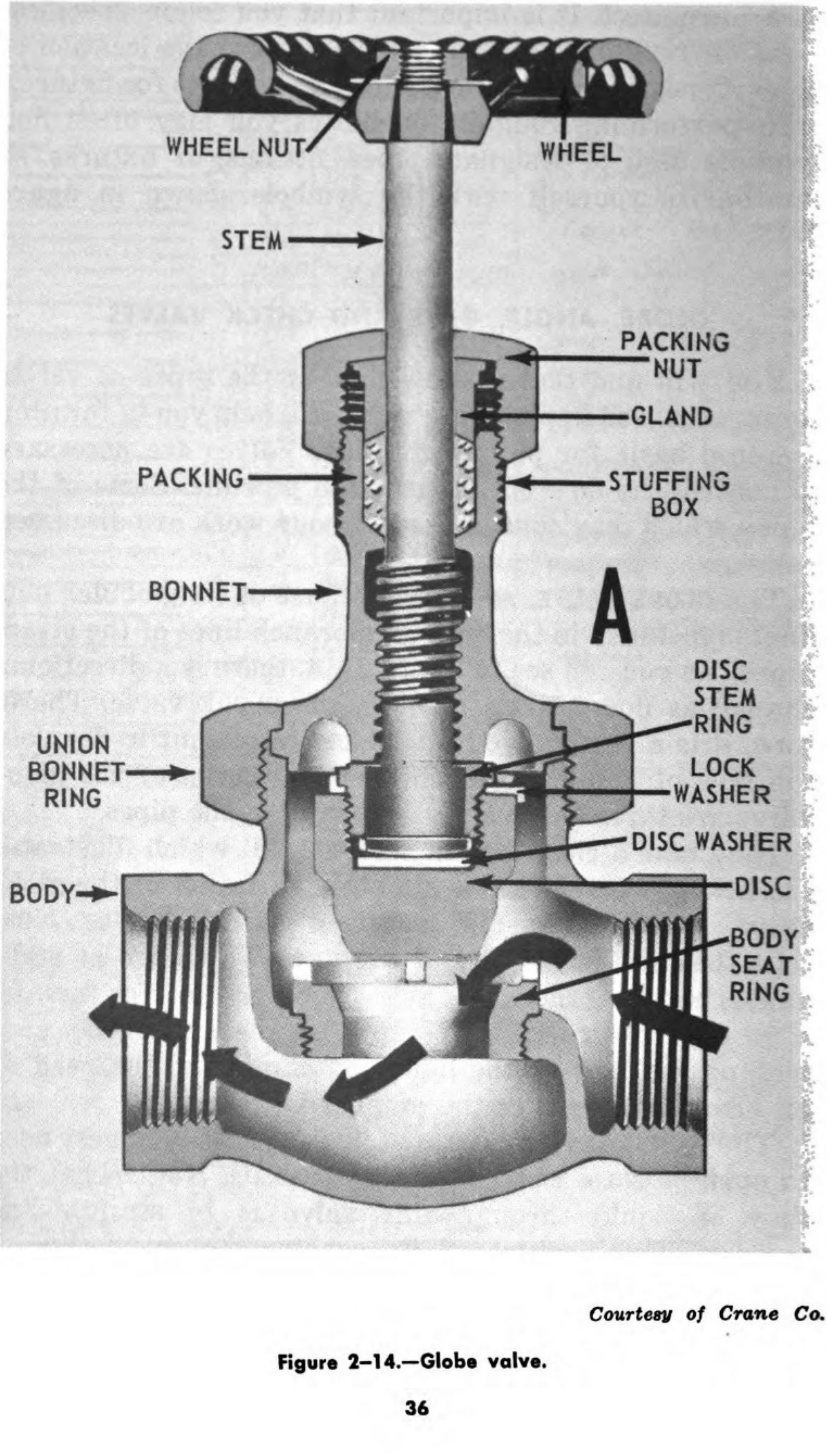
You will find that a knowledge of the types of valves commonly used in plumbing work will help you in forming a sound basis for plumbing skills. Valves are necessary to control the flow of water in the pipeline. Some of the types which may concern you in your work are discussed below.

The GLOBE VALVE, so-called because of its globular outline, is installed in the main and branch lines of the steam pipes. As you can see in figure 2–14, there is a directional change as flow travels through the GLOBE valve. Therefore, it is a good valve to use when you want to regulate the flow of liquid. Both the inlet and outlet of the globe valve are threaded to allow screwing to the pipes.

Now take a close look at figure 2–15, which illustrates the ANGLE VALVE. This is simply a variation of the globe valve, having the same operating characteristics. Note that the inlet and outlet of the angle valve are at right angles to each other. The angle valve is used for making a 90 degree turn in a line, and, at the same time, controlling the flow of the liquid. It eliminates the need of an elbow and reduces the number of joints.

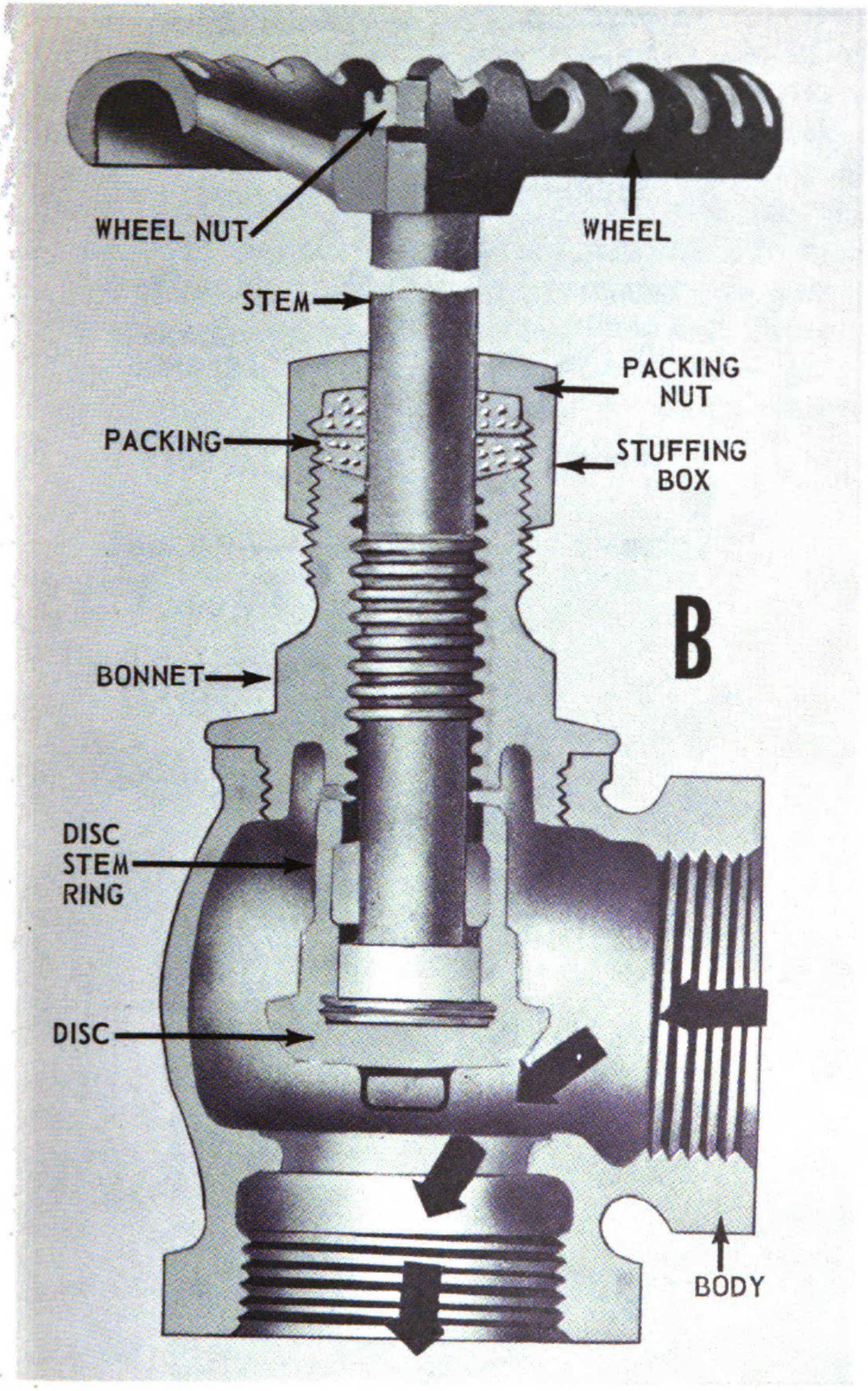
The GATE VALVE, illustrated in figure 2–16, is best used to open or close water mains of laterals. Notice that the flow of liquid through this valve is in straight-line fashion. This feature of its construction means small resistance to flow.

The CHECK VALVE consists of two types: the swing check and the lift check. Both types are illustrated in



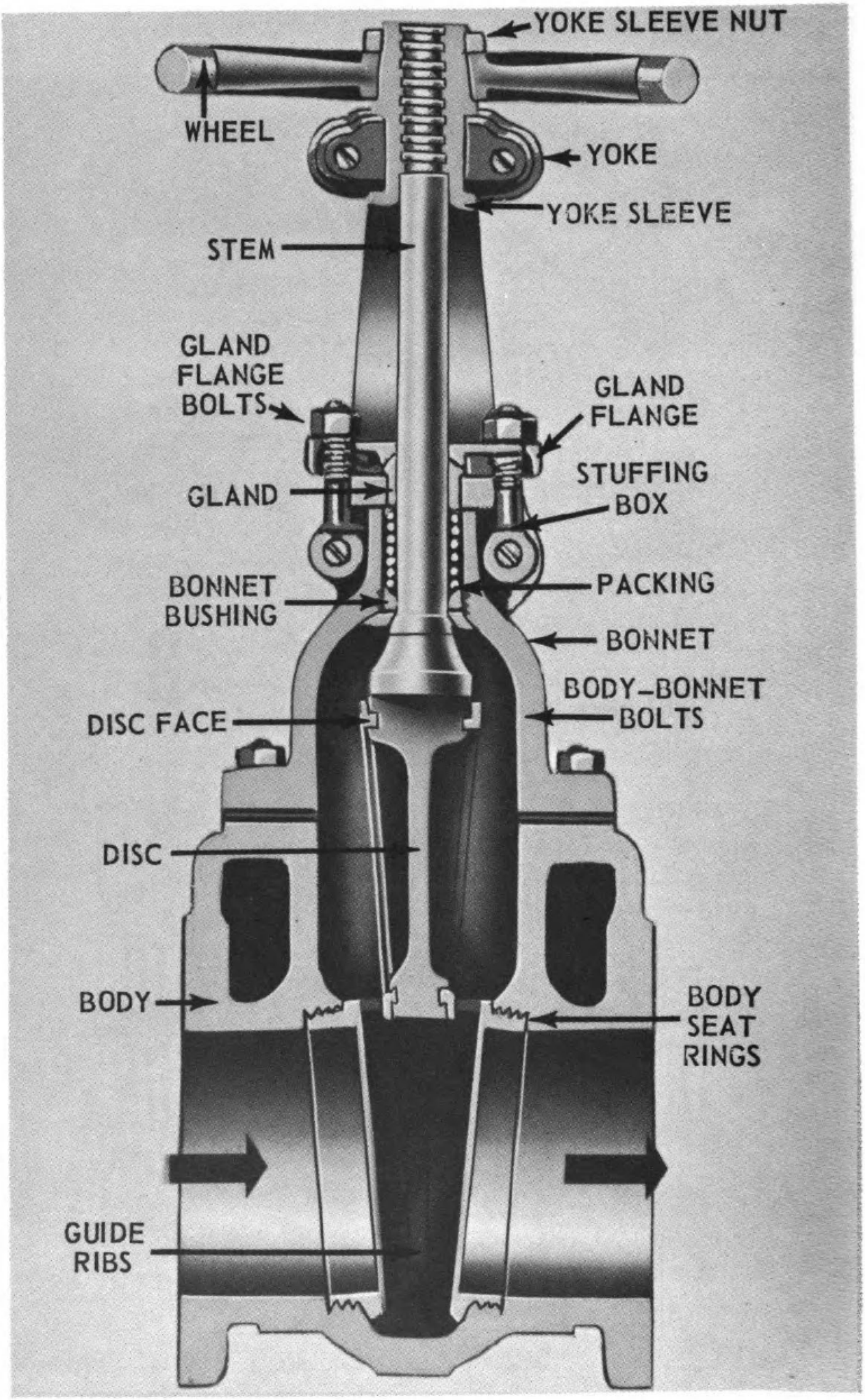
Courtesy of Crane Co.

Figure 2–14.—Globe valve.



Courtesy of Crane Co.

Figure 2–15.—Angle valve.

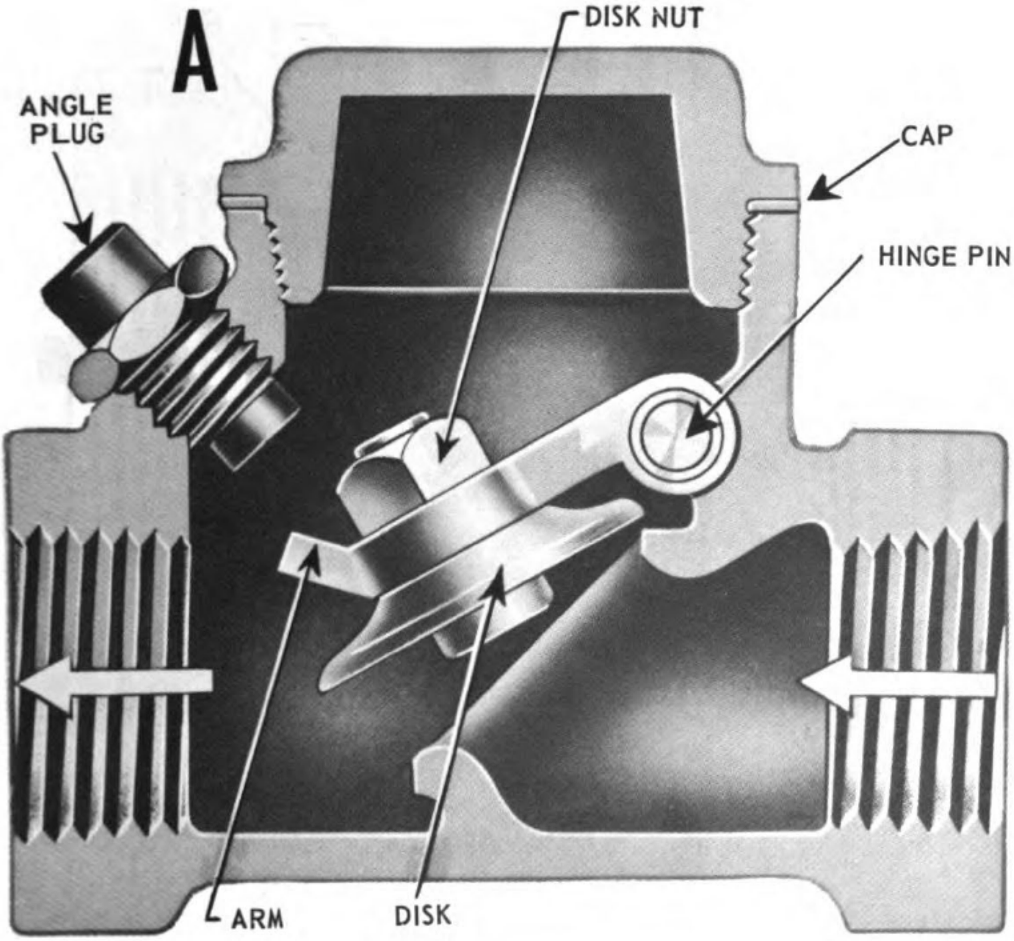


Courtesy of Crane Co.

Figure 2-16.—Gate valve.

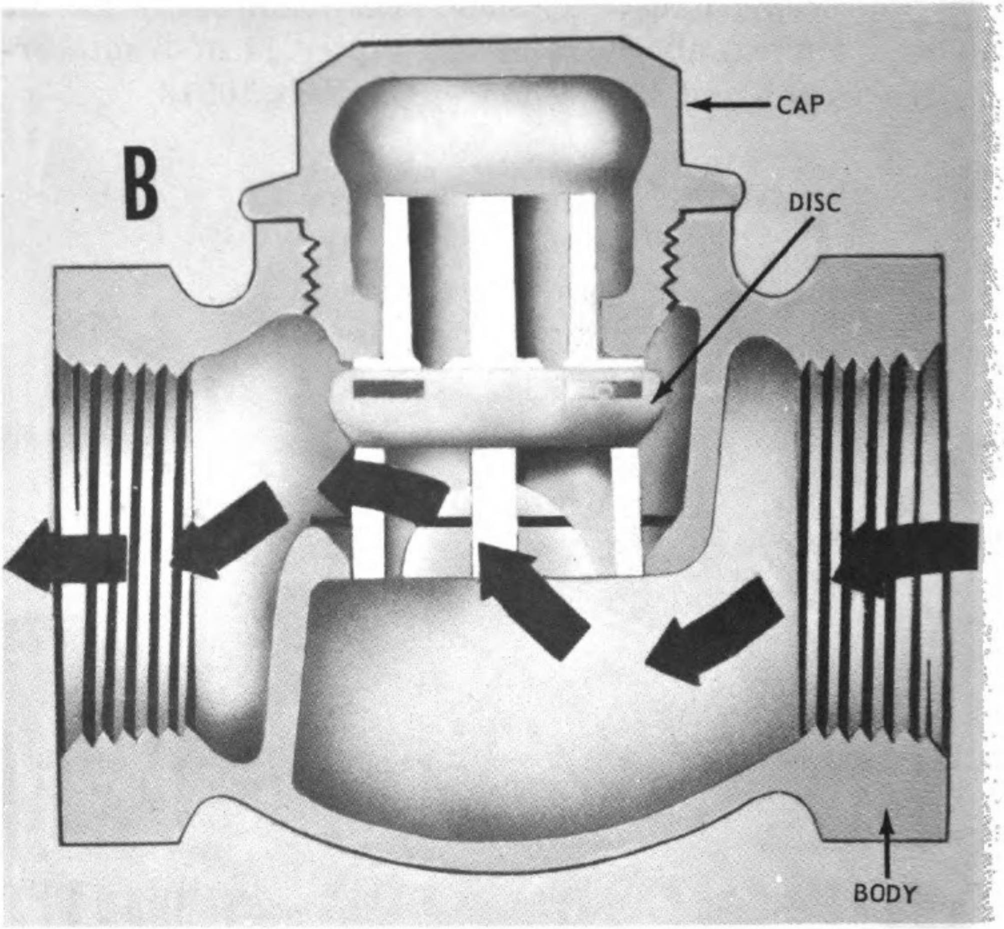
figure 2–17. The flow of liquid through the SWING CHECK VALVE is almost straight in its direction, being comparable to that of the gate valve. In the LIFT-CHECK VALVE the flow is uneven. Purpose of check valves is to check or prevent reversal of flow in the lines. As indicated in figure 2–17, neither the swing-check nor the lift-check has a handwheel or other means for operating it by hand. The flow of liquid in both types keeps them open; gravity and reversal of flow act to close the valves automatically.

If you would like to do some additional study on the valves discussed above, refer to chapter 14 of *Engineering, Operation and Maintenance,* NavPers 10813.



Courtesy of Crane Co.

Figure 2–17.—(A) Swing-check valve.



Courtesy of Crane Co.

Figure 2–17. Cont.—(B) Lift-check valve.

FLUSH VALVES

At military installations you will often find FLUSH VALVES being used for flushing urinals or water closets. A particular advantage which flush valves offer over flush tanks is that they require less water for flushing. The interval between flushing operations is also less with flush valves than with flush tanks. Actually, after flushing the fixture it serves, the flush valve is ready for reflushing within a matter of only a few seconds. Several types of flush valve are commonly used, including the DIAPHRAGM type illustrated in figure 2–18.

The diaphragm type valve has two chambers (upper and lower) which are separated by a relief valve. The UPPER chamber is connected to the main water supply by a bypass. The LOWER chamber is connected to the water supply line by a large diameter pipe (1 inch or more). The RELIEF VALVE separating the two chambers is mounted on a rubber diaphragm.

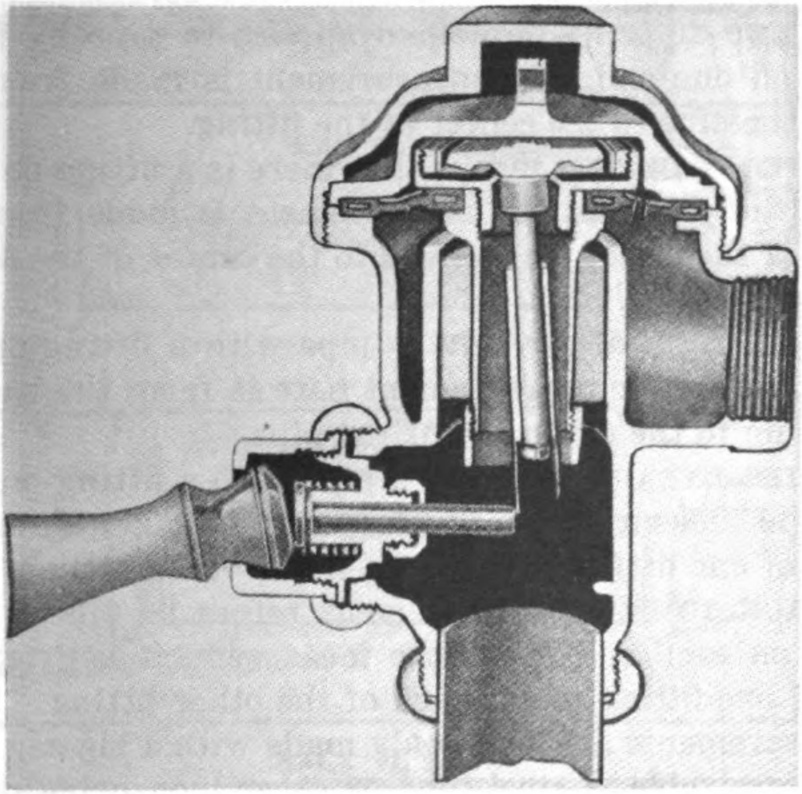


Figure 2–18.—Diaphragm type flush valve.

Here is what takes place when the diaphragm type valve (also known as a Sloan valve) is operated:

Water enters on the inlet side of the relief valve, causing an increase in pressure which forces the diaphragm upward. As the diaphragm rises, water is permitted to flow into the fixture which the valve serves. Within 10 seconds the water then forces itself around the bypass and provides equal pressure on both sides. This forces the diaphragm down on its seat and shuts off the flow of water.

MEASURING PIPE

The ability to measure pipe is an essential part of learning to lay out your work. Five different methods are commonly used in measuring pipe. They are: (1) end to center; (2) center to center; (3) end to back; (4) center to back; and (5) back to back. Each method is explained below, and each is illustrated in figure 2–19.

The END TO CENTER method applies to pipe having a fitting on one end. The measurement is made from the end of the pipe to the center of the fitting.

CENTER TO CENTER means that there is a fitting on each end of the pipe and the measurement is made from the center of the fitting on one end to the center of the fitting on the other end.

END TO BACK also refers to pipe with a fitting on one end only. But the measurement here is from the back of the fitting to the other end of the pipe.

CENTER TO BACK indicates a pipe with a fitting on each end. The measurement, in this case, is taken from the center of one fitting to the back of the other fitting.

A BACK TO BACK measurement refers to pipe with a fitting on each end. Here the measurement is from the back of one fitting to the back of the other fitting.

Measurements are commonly made with a zig-zag rule. Where desirable, a steel tape or other measuring device may be used.

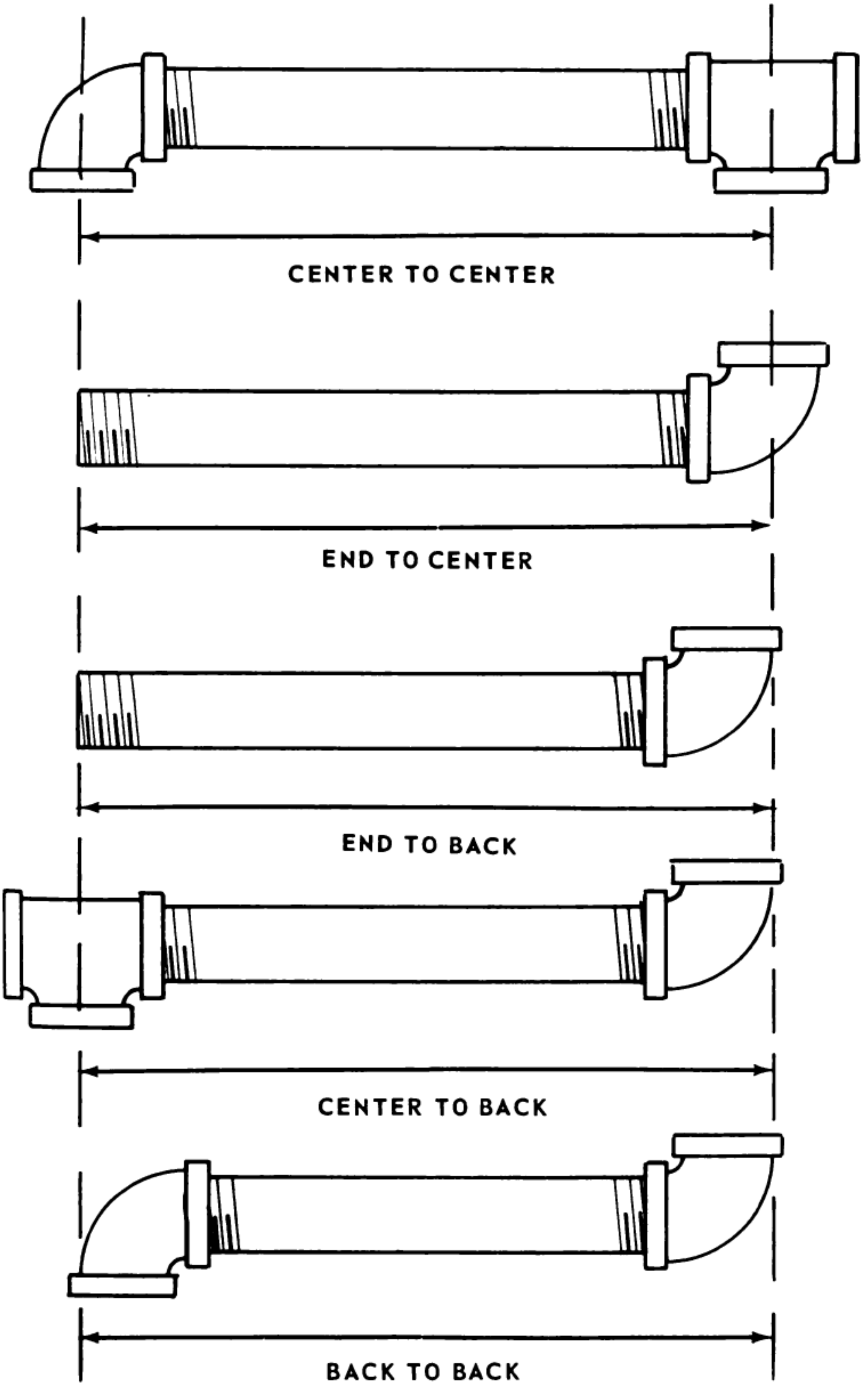


Figure 2-19.—Commonly used pipe measurements.

CLEANING PIPES

It is important to clean pipes thoroughly by blowing them out with compressed air or by swabbing before you install them. This is necessary to remove sand, dirt, and scale that has accumulated in the pipe during shipment and while in storage. Remember to wear safety goggles, and see that nobody is near the open end of the pipe while using the compressed air.

JOINING PROCEDURES

Various methods are used in joining pipe. This means that you must know the procedure to follow in making various types of joints. You must also know the type of joint required for the kind of pipe to be joined. Some of the common methods of pipe joining are discussed below. Study carefully each method given, and if possible, by all means get in plenty of practice in making these joints.

Joints in CAST-IRON soil pipe are generally made by calking. Where the soil pipe is made of CLAY (rather than cast iron) the cement mortar joint or the poured bituminous joint is used.

Cutting

As the first step in joining cast iron or clay soil pipe, cut the pipe, where necessary, to provide the length desired for the job at hand. The following instructions apply to the cutting of cast-iron soil pipe.

—Measure and mark the location of the cut as indicated at A, figure 2–20.

—Make a cut all the way around the pipe using a three-cornered file (see B, fig. 2–20).

—On standard or medium-sized pipe, simply tap the pipe lightly with a ball-peen hammer near the file cut until it breaks. On heavy pipe, use a cold chisel and hammer to deepen the cut made with the file (see C, fig. 2–20). Use a chisel that is not too sharp and make the first cut with it a light one. As the cut is made, turn the pipe on a plank.

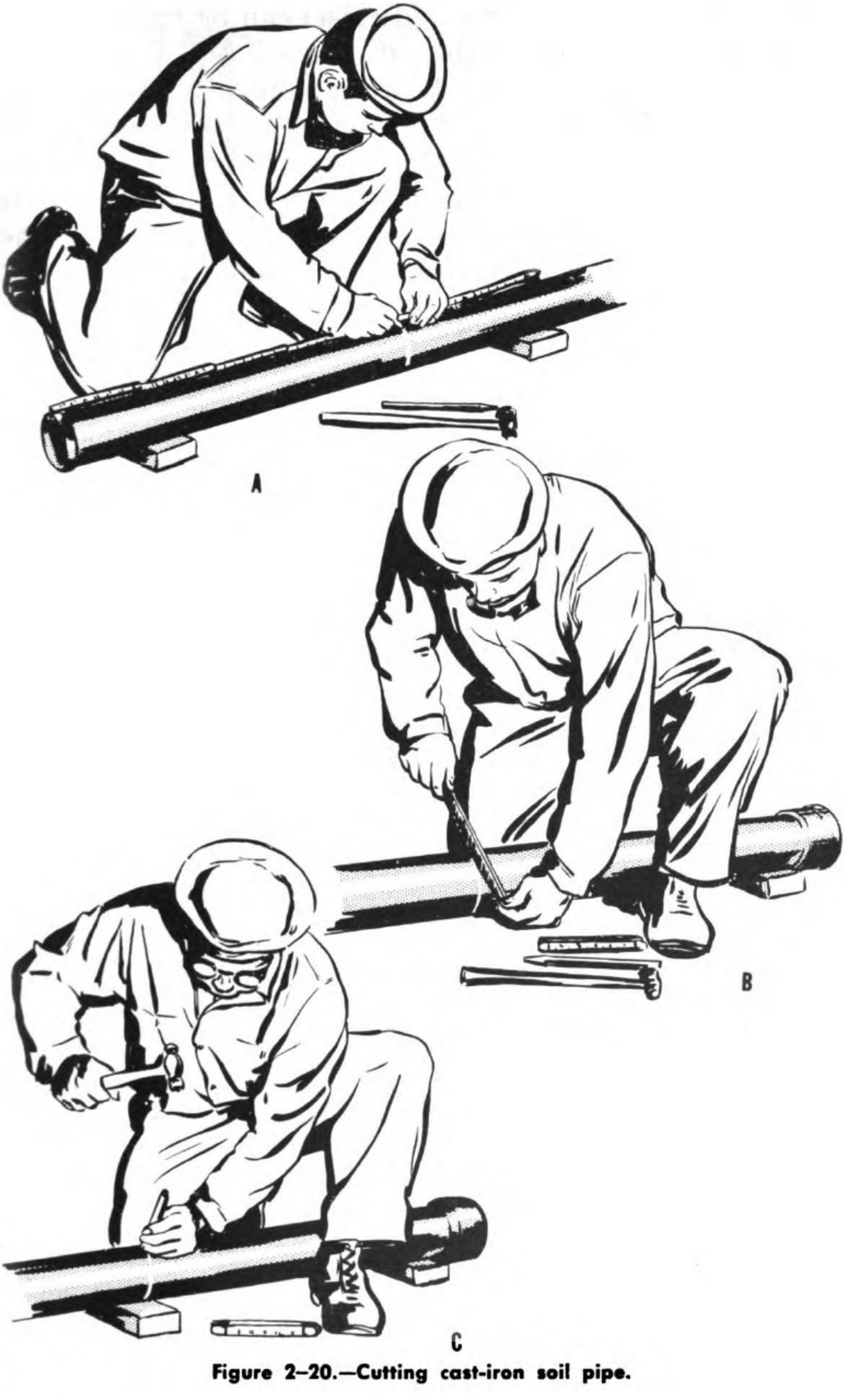


Figure 2–20.—Cutting cast-iron soil pipe.

Succeeding cuts with the cold chisel can be made deeper until the pipe breaks at the cut.

CLAY soil pipe is cut in about the same way as cast-iron soil pipe. After measuring and marking the pipe, lay it on a soft mound of dirt. Then make a groove around the pipe and with your cold chisel proceed to deepen the groove until the pipe breaks at the cut. Here, too, the hammer blows on your chisel must be light at first or the pipe will not break evenly at the cut.

Lead-Wool Joint

In making a LEAD-WOOL JOINT in cast iron soil pipe, you will need a yarning iron and calking iron (refer back to fig. 2–9). This is a cold-calked joint and should be used where a line is under water or in a wet place where molten lead can not be used.

Before actually starting the joint, place the spigot end of the pipe to be installed in the hub of the soil pipe. Make sure the pipe is securely blocked with braces to prevent shifting. It is also important that the pipe be centered in the hub so the thickness of the joint will be uniform.

With the pipe braced firmly and in proper position for joining, now make the joint, following the 3-step procedure given below:

Step 1: Pack oakum in the joint to within 1 inch of the top of the hub. Use a ball-peen hammer and yarning iron to tamp the oakum tightly in the joint.

Step 2: Pack two ½-inch layers of lead wool over the oakum.

Step 3: Tamp the lead wool tightly into the joint, using the calking iron and hammer (see fig. 2–21).

Poured-Lead Joint

Making a POURED-LEAD JOINT in cast-iron soil pipe will provide an opportunity for you to use the plumber's furnace and accessory equipment illustrated in figure 2–11, as well as the yarning iron and calking iron. Do

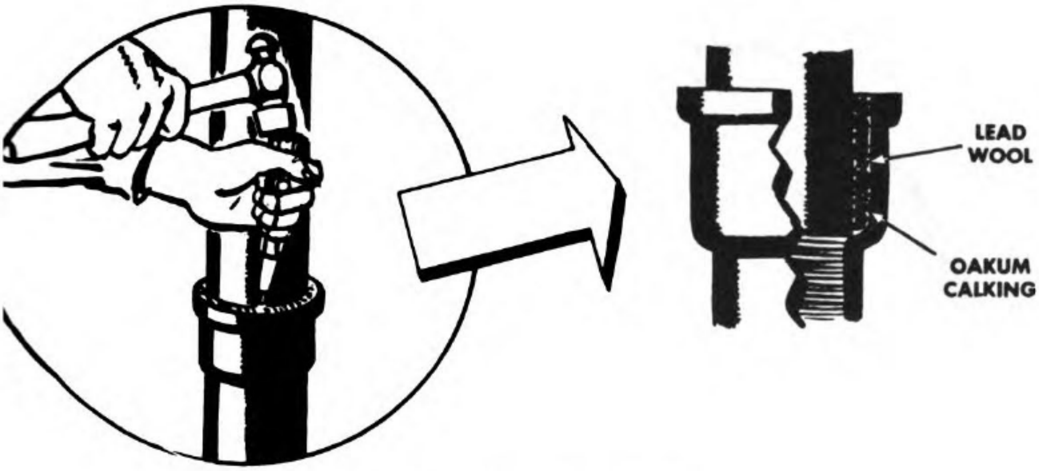


Figure 2–21.—Tamping lead wool.

not attempt to operate the plumber's furnace to be used for melting the lead without first checking the manufacturer's instructions and making sure you understand them.

In melting and handling lead, see that you exercise special care to eliminate fire hazards and to avoid injuries which might result from pouring molten lead into wet joints. To help you make good joints, follow these rules:

KEEP the melting-pot clean. Dross and lead oxide can be removed with a sharp chisel, after which the pot can be further cleaned with a wire brush.

PLACE one or two small cakes of lead in the melting pot and start the furnace. Make it a practice to always place the smallest area of the cakes on the bottom of the pot as this will promote rapid melting. As the first cakes melt, heat additional cakes to drive off moisture, then add them to the pot. Do not overheat or stir the melting lead, because that will cause oxide to form more rapidly.

ALWAYS preheat the ladle before you dip it into the lead. The reason for this is that a cold ladle chills and solidifies some metals. When the ladle is in steady use, keep it hot by hanging it over the edge of the pot. In loading the ladle, use the bottom of it to push back the dross on top of the lead, exposing enough clean lead so

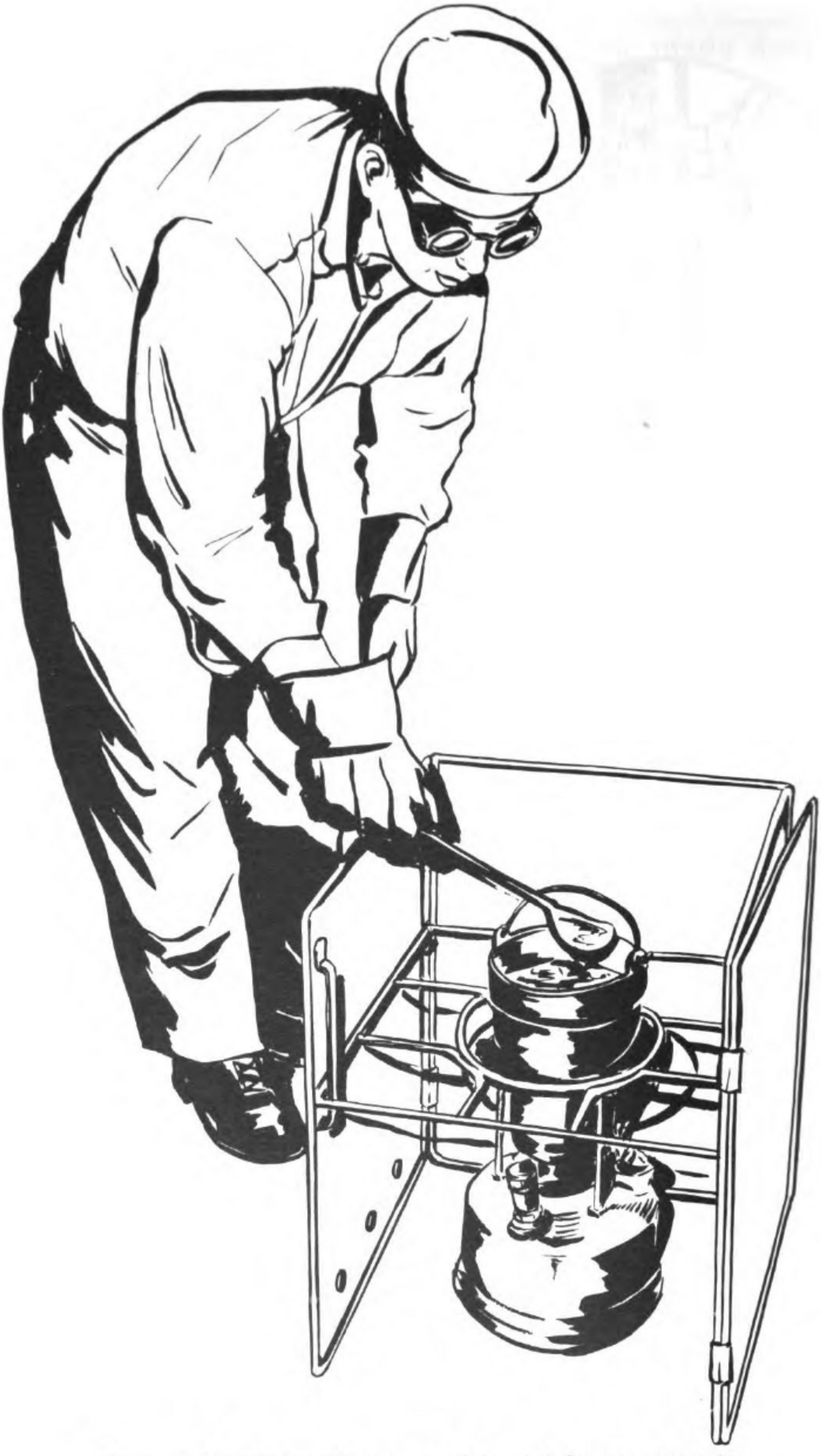


Figure 2–22.—Wear gloves, goggles, and heavy protective clothing when melting and pouring lead.

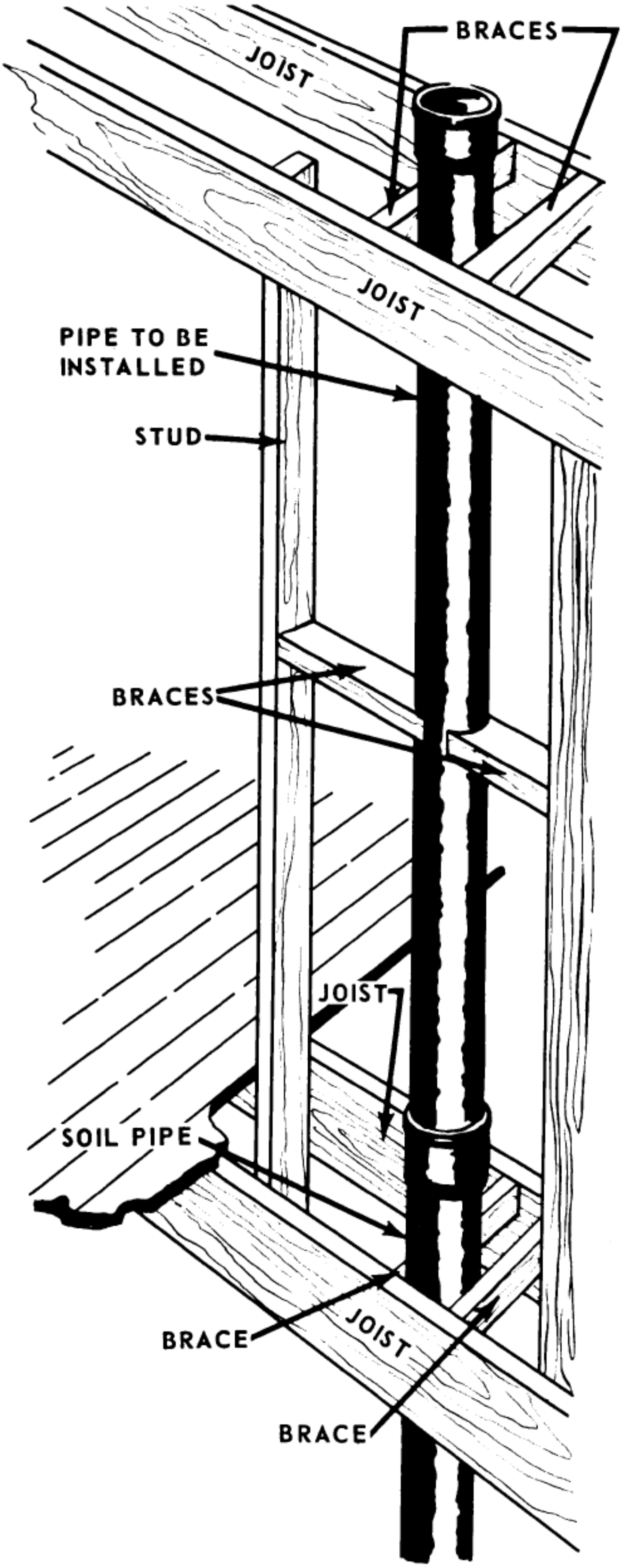


Figure 2–23.—Pipe to be installed should be securely fastened and braced before making lead-wool joint.

that the ladle can be filled and withdrawn without dross. Do not disturb the molten lead more than is necessary.

WIPE the hub and spigot ends of the pipe dry and free from foreign material before pouring the lead. Moisture causes molten lead to fly out of the joint and serious injury may result. Wear goggles, gloves, and heavy protective clothing when melting and pouring the lead. (See fig. 2–22.) Keep out of range of flying lead even though the joint appears dry. Also, see that drops of perspiration do not drop into the pot of hot lead.

IF lead must be poured into a wet hub, sprinkle powdered rosin or oil in the socket to reduce the tendency of the molten lead to fly out.

Before making a poured-lead joint, see that the pipe to be installed is placed in the hub of the soil pipe and is securely braced, as shown in figure 2–23. Here, too, the pipe should be kept centered to provide a uniform thickness of the joint. After attending to these preliminaries, make the joint according to the 3-step procedure given below:

Step 1: Pack oakum in the joint, using the yarning iron, to within about ¾ inch of the top of the hub.

Step 2: Using the ladle, dip out lead from the melting pot and fill the joint even with the hub. (See fig. 2–24.) As a pointer on technique: fill the joint with molten lead AT ONE POURING.

Step 3: For a smooth job, when the lead hardens, tamp it lightly all the way around with calking iron and hammer to make the joint watertight.

Horizontal Lead Joint

If the joint to be poured is HORIZONTAL (as well as inverted or upside down) you will need to use a joint runner. The procedure is practically the same as described above for the poured-lead joint. Pack the joint with oakum. Then place the joint runner around the spigot end of the pipe and push it flush against the bell end of the other pipe, sealing the joint except for a small hole at the top

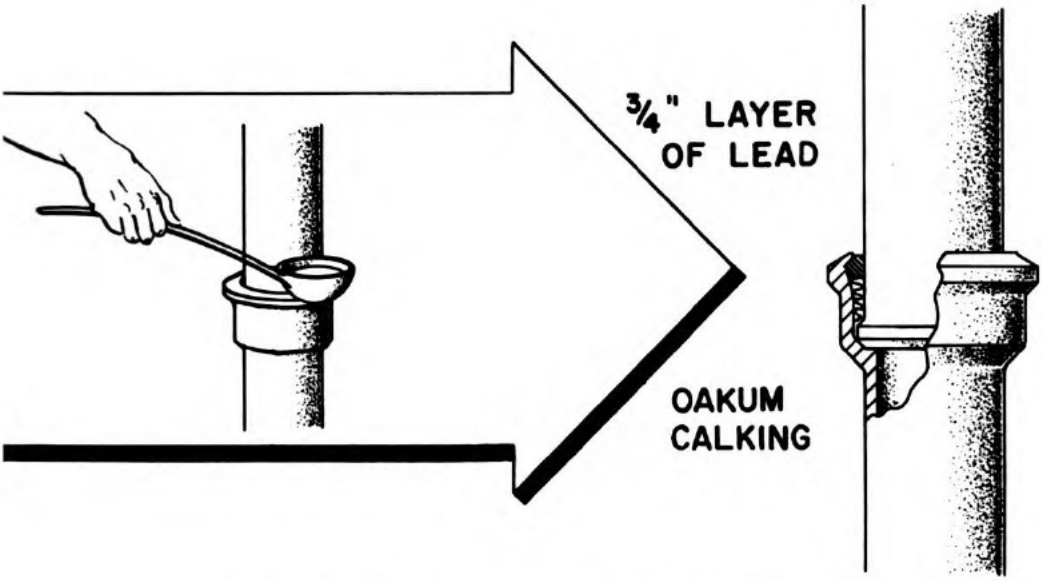


Figure 2–24.—Pour lead even with top of hub.

of the pipe where the runner is clamped. Place oakum in the opening under the runner at the clamp and then pour the lead into the joint. (See fig. 2–25.) When the lead has cooled, remove the runner and hammer the lead lightly, with the calking iron, to ensure tightness.

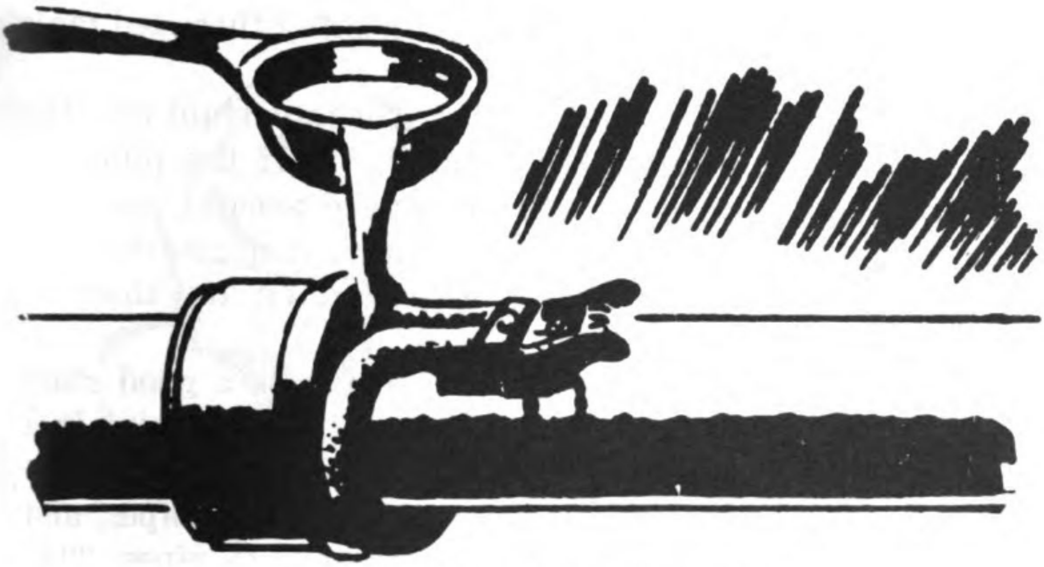


Figure 2–25.—Pouring lead into joint.

Cement Mortar Joint

When it comes to making a CEMENT MORTAR JOINT in CLAY pipe, follow the procedure below, in the order given:

—PREPARE a mixture of mortar, consisting of equal parts of sand and cement.

—ALINE the pipe and, using a trowel, squeeze mortar into the joint.

—BANK the mortar around the joint and smooth it with the trowel.

—SCRAPE or swab out all excess mortar inside the pipe to prevent it obstructing the line later.

Poured Bituminous Joint

The poured bituminous joint is the preferred joint for vitrified clay pipe. A gasket or oakum is calked in the joint, a runner attached, and the bituminous material poured into the runner, in a manner similar to the pouring of a lead joint in cast-iron pipe. The joint compound should be finished to a neat bevel for the full depth of the bell and at 45 degrees with the barrel surface. The interior of all joints should be cleaned of surplus compound.

Threaded Pipe Joints

THREADED PIPE JOINTS are commonly used on galvanized steel and galvanized wrought-iron pipe. This method of pipe joining involves connecting threaded male and female ends together.

To obtain a tight threaded joint, it is important that the threads be clean and in good condition. If the pipe has been exposed to the weather or banged around, see that the threads are checked very carefully. If necessary, run a tap or die over the threads to straighten any that are damaged.

Cleaning both ends with a wire brush is a good start in making this joint after you have secured the pipe in a vise. Next, smear a good thread lubricant on the male pipe threads. Use red lead or white lead for water pipes, and mixed powdered graphite and oil for steam pipes. This "pipe dope" is not used inside the pipe.

Start the joint by hand and turn it up as far as you feel it will go. Then slowly screw the remaining section of the pipe into the joint and tighten it with a pipe wrench. Do not use a hickey, or oversized wrench, or too much pull. Not all of the male threads need go into the joint. If all the threads are used, the wedging action of the tapered thread may cause the fittings to split.

How tight should you make a joint? Experience is the best teacher. Usually you will have two or three unused threads on a properly threaded pipe. If these steps are followed and the threads have been made properly, the joints will be tight for pressures up to 1,000 pounds.

Victaulic Couplings

VICTAULIC COUPLINGS, consisting of a rubber gasket, two nuts and bolts, and two steel half-rings, are used for

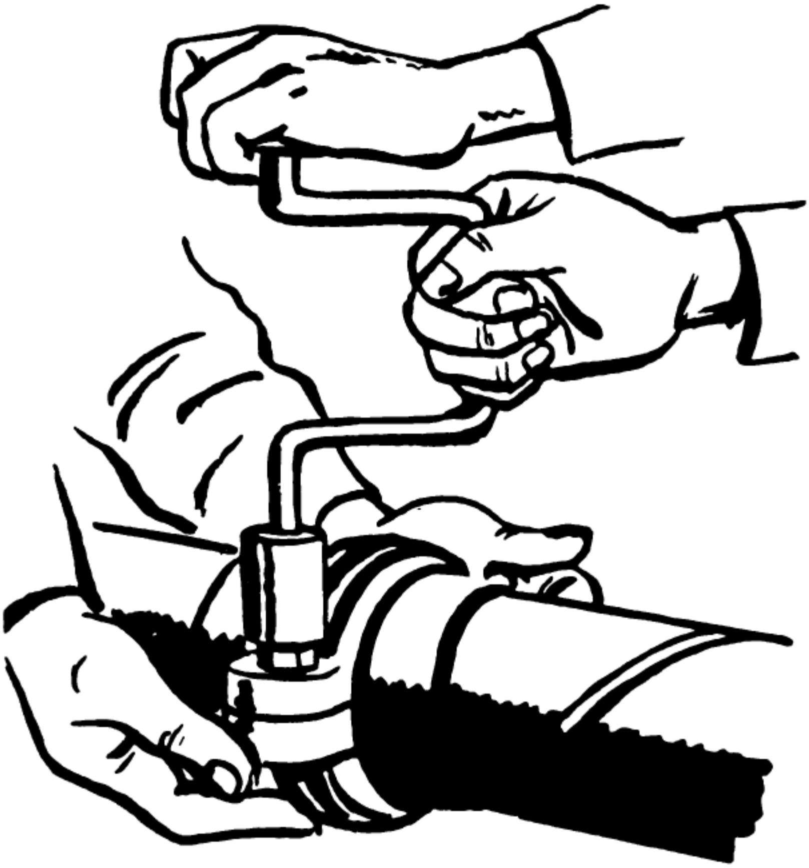


Figure 2–26.—Bolting victaulic couplings.

black-steel water main pipes. As the first step in the installation procedure, wipe the ends of the pipes to remove any dirt or grit that may be present and grease the inner surface of the coupling. Now place the gasket flush with the end of the pipe already installed.

Next, aline and butt the pipes together. Then slip the gasket over the ends of the pipes so that it bears on both pipes. Place the half-rings over the rubber gasket and then bolt them tight with a speed wrench (see fig. 2–26). Tighten the bolts evenly, making one or two turns alternately on each bolt to avoid damaging the bolt threads. The bolts SHOULD NOT be turned too tight.

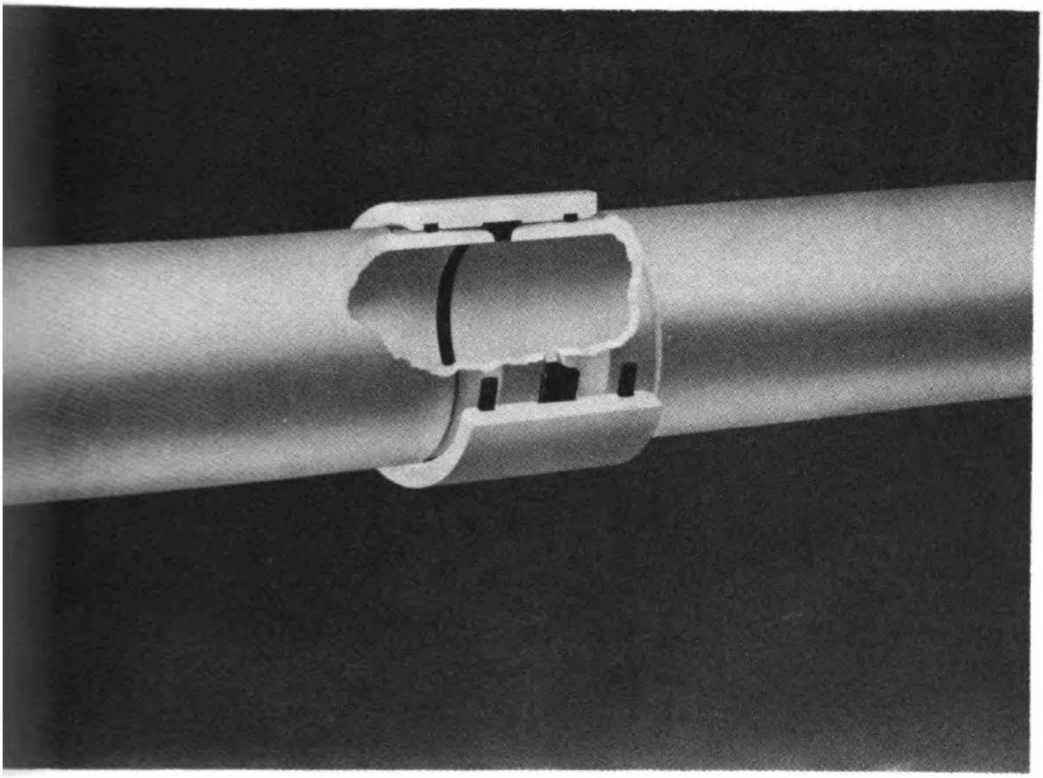
Rubber-Ring Coupling

Joints in asbestos-cement pipe are commonly made with a specially designed COUPLING having three rubber SEALING RINGS. The three rings are fixed in grooves at the factory—ready for assembly.

Figure 2–27 shows you a cut-away view of a completed joint with the three rings in proper position. As each pipe moves into position, during the process of assembly, the rubber rings in the two outer grooves of the coupling are compressed to seal the joint tightly. The T-shaped center ring forms a seal between the pipe ends. It eliminates jogs and pockets, and provides for uninterrupted flow of sewage. In this type of joint you have a tight and flexible connection.

A joint like that illustrated in figure 2–27 can be assembled entirely by hand. After checking to make sure the rings in the grooves of the coupling are in correct position, use the following two-step procedure, illustrated in figure 2–28, to make the connection.

1. Apply a thorough coating of lubricant to the male end of the pipe—all the way around. If a special lubricant supplied by the manufacturer is not available, a jelly-like soap solution can be prepared and used instead.



Courtesy of Johns-Manville

Figure 2–27.—The Johns-Manville Ring-Tite Coupling.

2. Pull or push the pipe together, as indicated at B, figure 2–28, and the joint is complete.

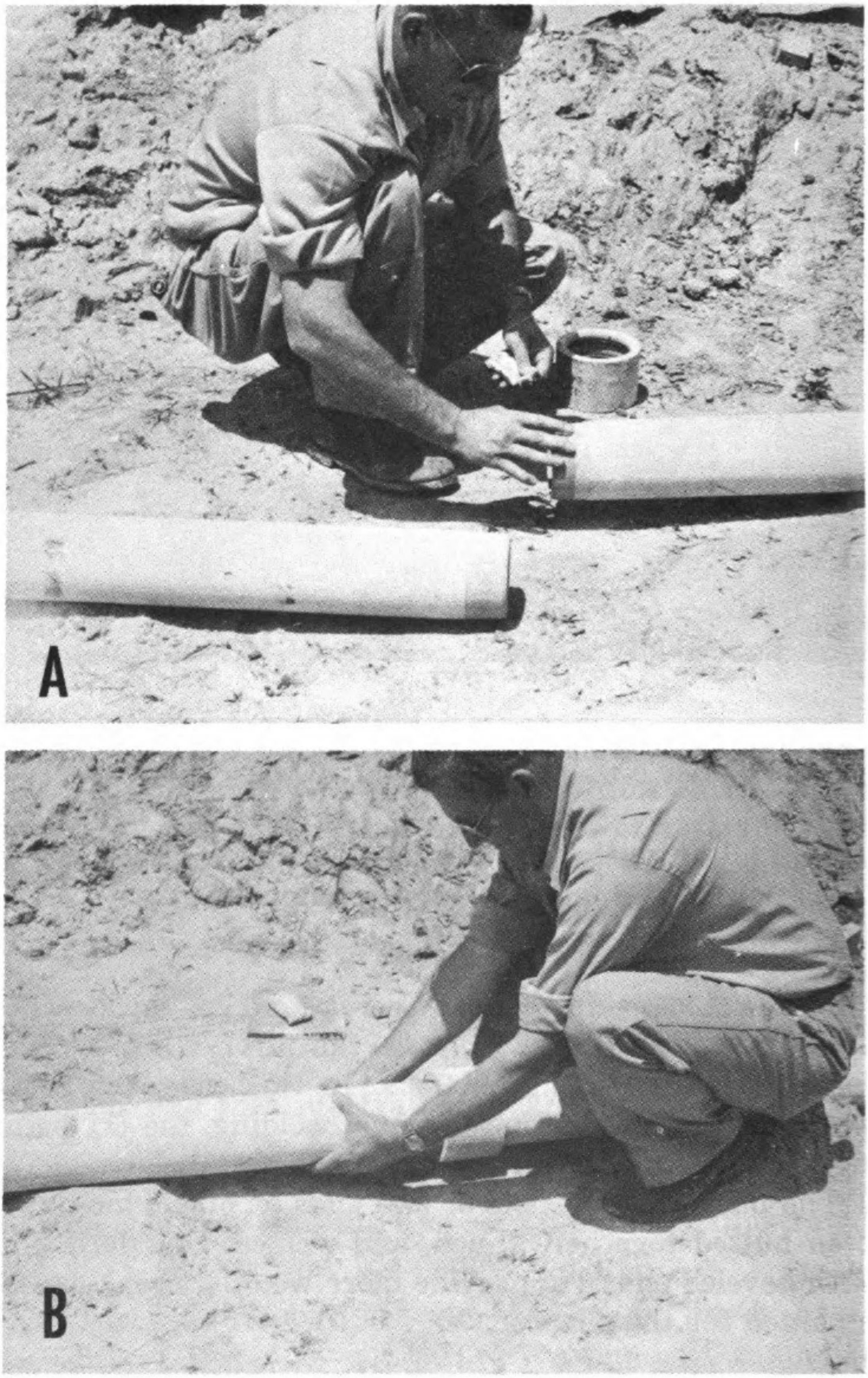
Welded Joint

If a WELDED joint should be required on thick-walled STEEL-PIPE, it will probably be the BUTT WELD type of joint illustrated in figure 2–29. In this case, the Steelworker is the man to do the actual welding, the UT being responsible only for the lay-out of the pipe.

The butt joint consists of two ends of pipe which have been butted together, alined, and welded. Standard pipe with beveled ends (to provide more welding area) can be obtained for the purpose.

Soldered Joint

Copper tubing is usually joined by SOLDER. To make a good soldered joint, it is important that the parts to be



Courtesy of Johns-Manville

Figure 2–28.—Assembling joint in asbestos-cement pipe.

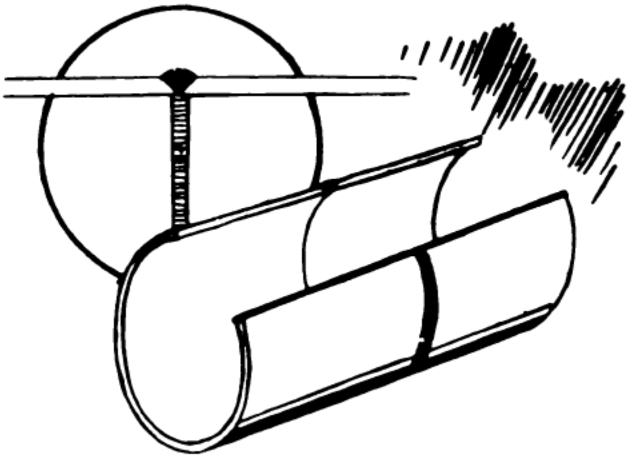


Figure 2–29.—Butt joint.

joined be properly prepared before starting the soldering operation. First you will need to square the ends of the tubing and to remove any burrs that may be present on both the inside and outside of the tubing. The next step consists of thoroughly cleaning the outside surface of the tubing and the inside surface of the fitting. To clean an oxidized surface, use an emery cloth or steel wool. Now apply an even coating of flux to the cleaned surface of the tubing and fitting. A brush can be used for this.

The next step involves assembling the job. You will find it a good idea when fitting the parts together to turn the fitting a little in order to spread the flux. Now heat the joint with your blow torch to a good soldering temperature.

When the proper temperature is reached, apply the solder at the edge of the fitting and fill the joint completely. Wipe off any excess solder with a damp cloth while the solder is still in a molten state.

PIPE SUPPORTS

Because of the weight imposed by pipes and water, you will need to install hangers to provide support for overhead pipework to keep it in alinement. Figure 2–30 shows you three types of hangers which can be used for this purpose.

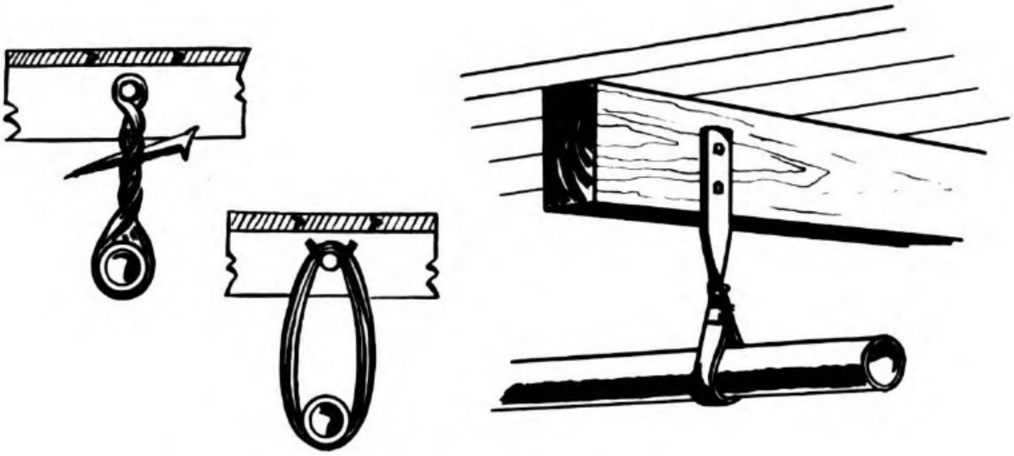


Figure 2–30.—Use of strap iron and wire loop hangers to support overhead pipework.

When possible, avoid making notches in beams and joists for pipes to run through. If notching should become necessary, by all means see that reinforcements are provided to strengthen the beams to guard against failure when the pipes are loaded.

When a joist is notched at the TOP, make sure a block

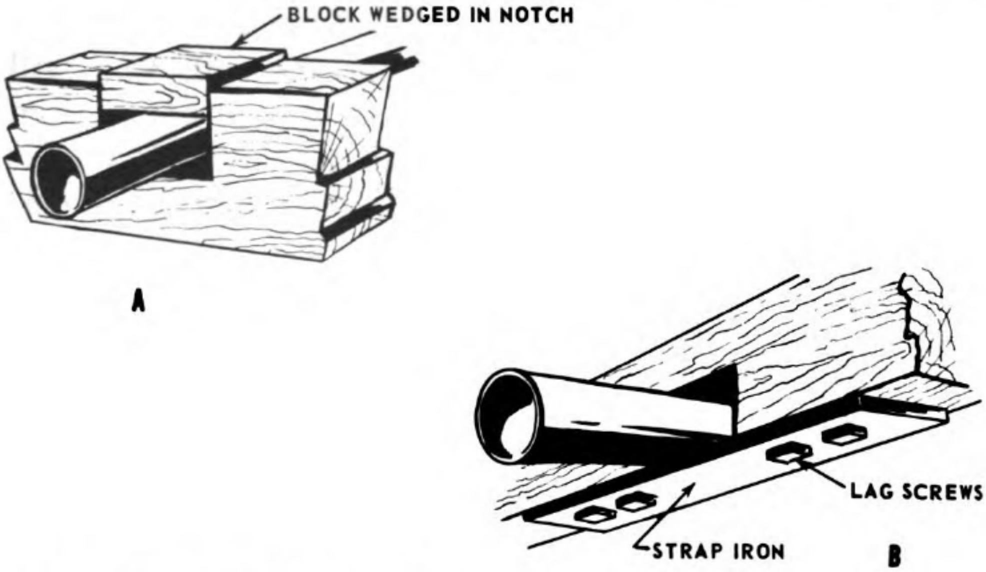


Figure 2–31.—(A) Using wedged block as reinforcement for joist notched at top. (B) Using steel strap as reinforcement for joist notched at bottom.

is wedged in it as illustrated at A, figure 2–31. When a joist is notched at the BOTTOM, always fasten a steel strap underneath, as shown at B, figure 2–31.

TRAPS AND VENTS

Traps are a necessary part of the plumbing installation because they provide a means of preventing sewer gases from entering the building. Protecting occupants in a building against exposure to sewer gases is vitally important since many of these gases can cause serious illness and even death.

The Utilities Man is concerned with both external and integral type traps. In the external category, common types include the **P**-trap and the **S**-trap illustrated in figure 2–32. The **P**-trap forms the shape of the letter "**P**" and is used when the waste pipe is in the partition. The **S**-trap forms the shape of the letter "**S**" lying on its side. Its use is desirable when the waste pipe is in the floor. Both **P**- and **S**-traps are installed, usually, under the vertical outlet of the fixture.

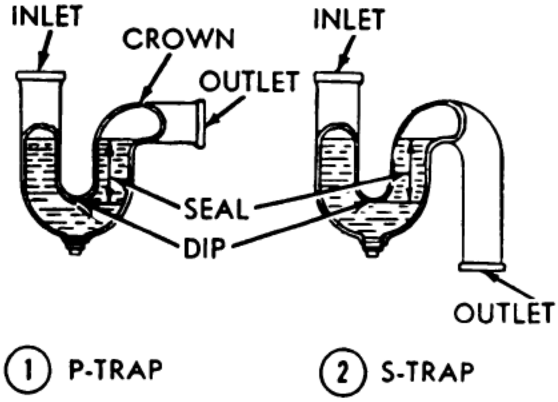


Figure 2–32.—(1) P-trap. (2) S-trap.

An integral-type trap is the kind used in fixtures such as water closets. Here the trap is located inside, rather than outside, the plumbing fixture. With the inside trap, waste removal is short and direct. Vents for water closets are connected above the flush tank.

The term TRAP SEAL refers to the water which is held in the bent portion of a fixture trap (fig. 2–32). True to its name, the trap seal forms a "seal" against the passage of sewer gases through the inlet (or fixture) end of the trap, and from being discharged into the building.

To prevent the siphonage of the trap seal in fixture traps, air from outside the building is introduced to the outlet (or discharge) end (fig. 2–32) of the trap. The air is supplied through pipes or VENTS. This air provides a pressure on the outlet end of the seal which is equal to pressure on the inlet end.

To avoid confusion, let us explain that atmospheric pressure, at sea level, is about 14.7 pounds per square inch. This pressure remains virtually constant on the inlet end of the water seal. Obviously, a greater or lesser amount of pressure on the outlet end of the trap seal would force the water in the direction of least resistance. Since the air supplied by the vent to the outlet end provides a pressure equal to that at the inlet end of the trap, the trap seal can not escape through siphonage.

All vent systems should be provided with a main vent and a main soil and waste vent. A MAIN VENT may be defined as a vertical length of pipe which connects fixture vents to the main soil and waste vent. (See fig. 2–33.)

The term MAIN SOIL AND WASTE VENT refers to the portion of the stack which extends above the highest fixture branch. Note in fig. 2–33 that this vent extends through the roof. Actually, it is an extension of the main soil and waste stack.

The MAIN SOIL AND WASTE STACK, as indicated in figure 2–33, is installed in a vertical position. Its purpose is to carry liquid waste not containing human excrement.

Various types of vents are used in the ventilation of fixtures; even in the best of installations you may find several different types of vents. The selection of a particular type depends largely on the manner in which the plumbing fixtures are to be located and grouped. Some of the common types of vents which you may use frequently in your work are mentioned briefly.

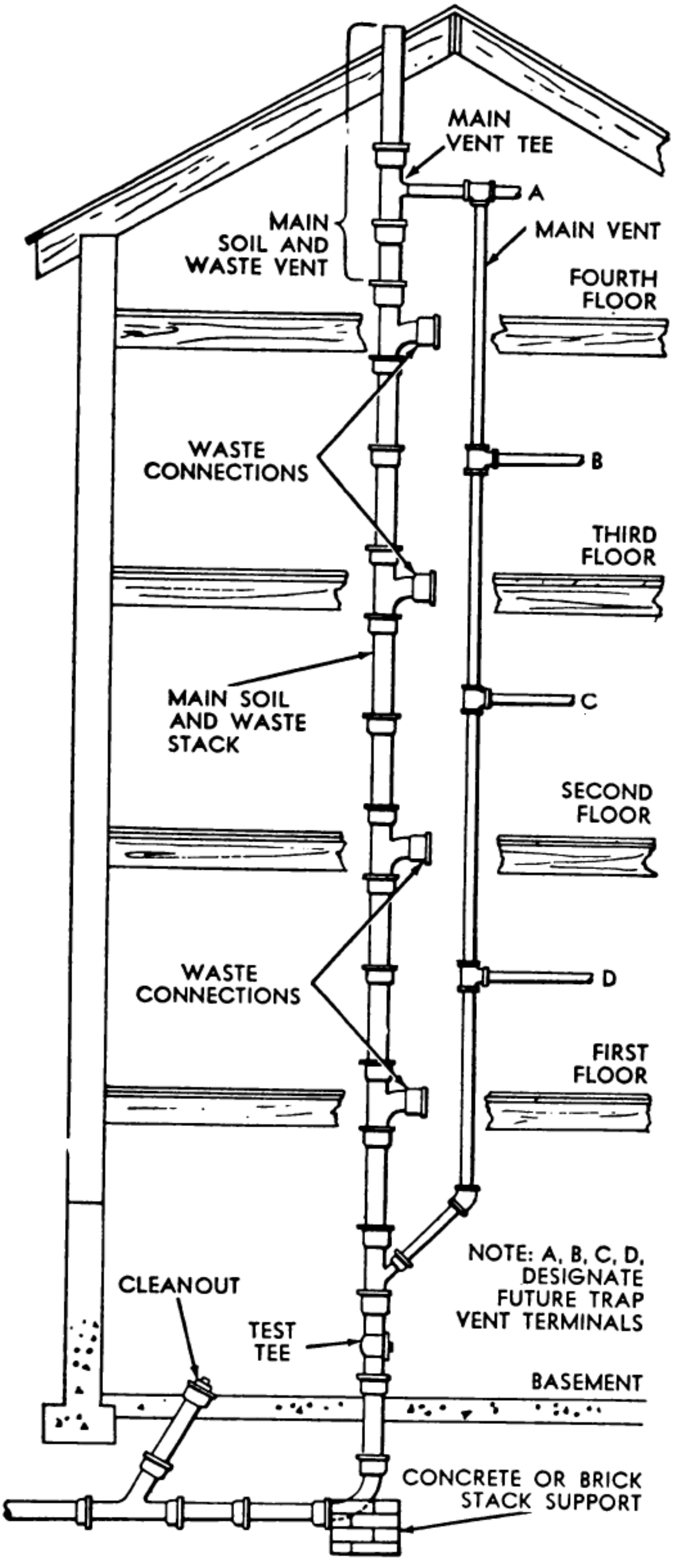


Figure 2–33.—Typical stack and vent installation.

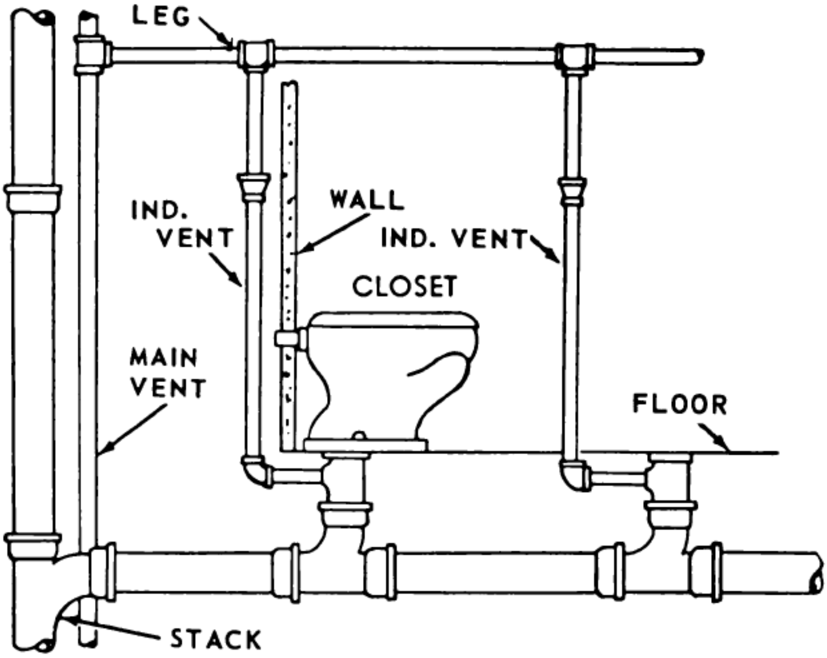


Figure 2–34.—Individual (or back) venting.

A BACK VENT, also known as an INDIVIDUAL VENT, is a vent which connects the main vent with the individual trap underneath or behind a fixture. This method of venting is illustrated in figure 2–34.

When installing two or more fixtures on the individual vent basis, it is important that the leg (see illustration) connecting the individual vents to the main vent be of sufficient size to carry the total load.

A UNIT VENT is used for the purpose of venting two traps to a single vent pipe, as shown in figure 2–35. The unit vent can be used when a pair of lavatories are installed side-by-side, as well as when hung back-to-back on either side of a partition (as shown in illustration). A point to note is that the waste from both fixtures discharges into a double sanitary tee (as shown in fig. 2–35).

A CIRCUIT (or LOOP) VENT is a vent used to serve a group of fixtures. As indicated in figure 2–36 a circuit vent extends from the main vent to a position on the horizontal branch between the last two fixture connections. Make sure that not more than 8 fixtures are put on any one circuit. If you have more than 8 fixtures to be circuit

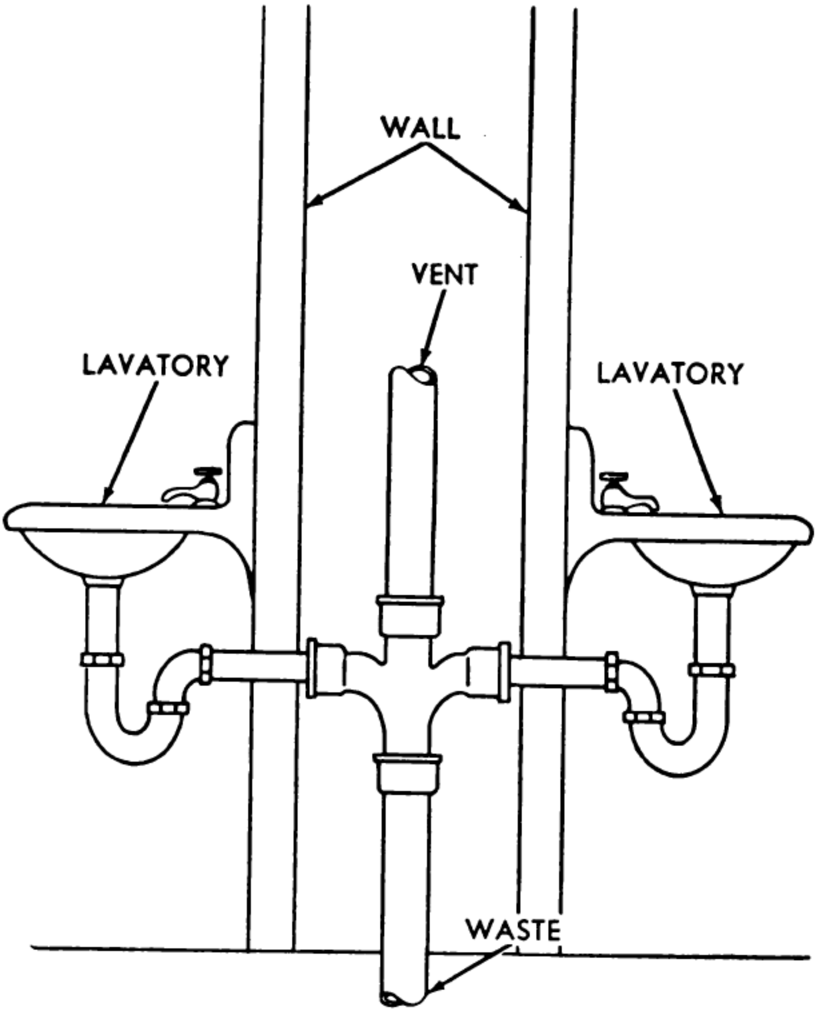


Figure 2–35.—Two fixtures unit vented.

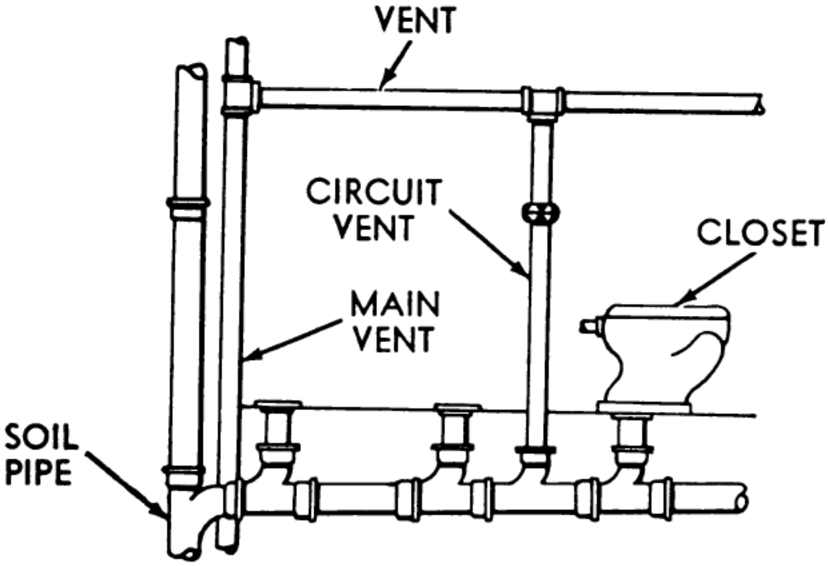


Figure 2–36.—Water closets circuit vented.

vented, use 2 circuits instead of one. In this type of vent, water and waste discharged by the last fixture will tend to scour the vents of other fixtures on the line.

A vent pipe in which liquid wastes flow through a portion of it is known as a WET VENT. This type may be used on a small group of bathroom fixtures, such as a lavatory, water closet, and shower, as illustrated in figure 2–37. The pipe for a wet vent installation should be sized to take care of the lavatory, water closet, and shower; it should never be under 2 inches in diameter. As indicated in figure 2–37 the lavatory should be individually vented. This is necessary to prevent loss of the trap seal through indirect siphonage. Another point to note in connection with the lavatory is that the relatively clean water discharged from it will tend to scour the wet vent, in that way preventing an excessive buildup of waste material in the vent.

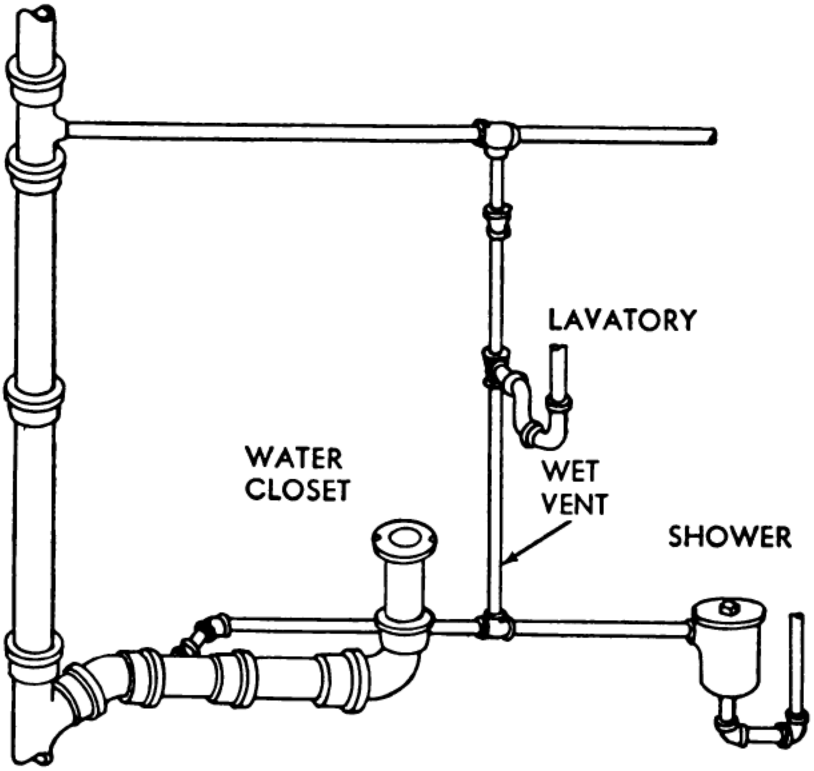


Figure 2–37.—Wet vent.

Installation Pointers

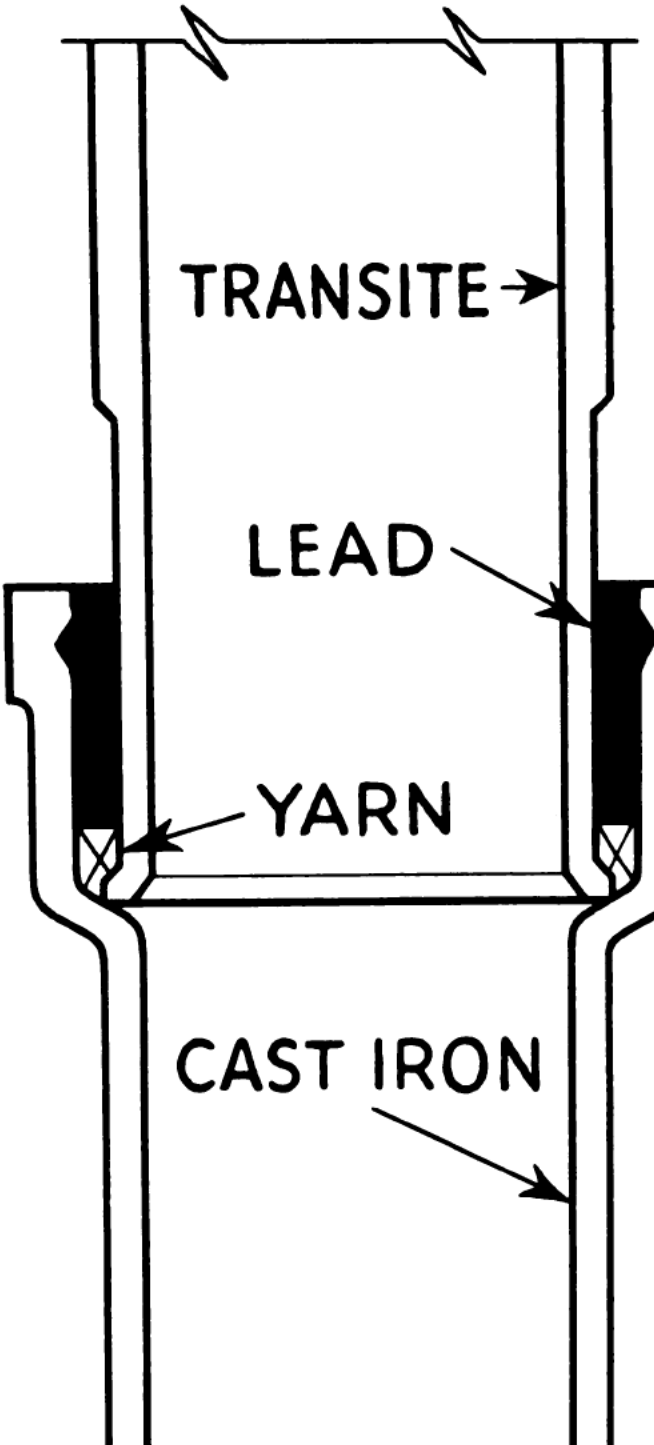
A venting system must be properly installed if it is to serve its intended purpose and require a minimum of repair and upkeep. This section will give you some important pointers that should prove useful in duties involving the installation of vent systems.

Referring again to figure 2–33, notice that a MAIN VENT TEE is used to form a junction between the main vent and the main soil and waste vent. This is a tapped tee, having a 2-inch side outlet. It should be installed by calking in the vertical stack, at least 3 feet above the highest soil pipe fixture branch. After this has been done, the vertical stack should be extended, full size or larger, through the roof to form the vent terminal. The pipe must extend at least 12 inches above the roof.

The opening in the roof through which the main soil and waste vent runs must be properly waterproofed. Roof flashing is used for this purpose. A roof flashing is a specially constructed device which, ordinarily, is made of a square piece of galvanized iron with a lead collar soldered to it. Flashing is available in different sizes. The size of flashing needed for a particular job is determined by the size of the main soil and waste vent.

When installing the roof flashing on a shingled roof, extend it under two courses of shingles above the pipe. On a flat roof, place it between layers of the roofing material and have the finishing layer over the top of the flashing. To complete the installation on either type roof, always apply a coat of roofing cement as added protection against leakage.

In freezing climates, suitable provision must be made to prevent closure of the main soil and waste vent at the roof outlet by freezing. We might explain here that the air discharged by the main stack and waste vent is very humid, in which case condensation occurs. Unless proper precautions are taken, this condensation will freeze if exposed to extreme temperature.



Courtesy of Johns-Manville

Figure 2–38.—Vent installation using Johns-Manville Transite plumbing vent pipe.

One method by which you can prevent this happening is to increase the pipe to a size or two larger than the vertical stack.

Another method involves the installation of a high lead flashing which will provide an insulating pocket of air between the flashing and the end of the main soil and waste vent above the roof. Being open to the heat of the building, the air pocket makes possible an intermediate warming area for gases leaving the main soil and waste vent.

Materials used in vent piping ordinarily include galvanized steel, wrought iron, or cast iron. At times, brass and copper piping are used. Asbestos-cement pipe can also be used for venting soil and waste pipe. A single length of this pipe is often sufficient for venting a stack. For such an installation, pipe is available with a machined end. This end is placed in the bell of the soil or waste pipe, and the connection made by yarning, leading, and calking. (See fig. 2–38.)

In all phases of the venting system, the use of proper-sized piping is an important consideration. A good point to remember is that the diameter of the vent stack or main vent must be not less than 2 inches, and at least one-half the diameter of the soil or waste stack. The actual diameter depends on the developed length of the vent stack and on the number of fixture units installed on the soil or waste stack. The diameter of a stack vent should be at least as large as that of the soil or waste stack.

To familiarize yourself with some of the important details concerned with the sizing of vents it will pay you to make a careful study of the specifications given in table 1 and table 2 on page 69. Vents can be sized by applying the fixture loads in table 1 to the load limits in table 2 for each pipe size.

Soil pipe BRANCHES are horizontal branch takeoffs which are used to connect various fixtures and the vertical stack. (See fig. 2–39.) One method of installing a branch

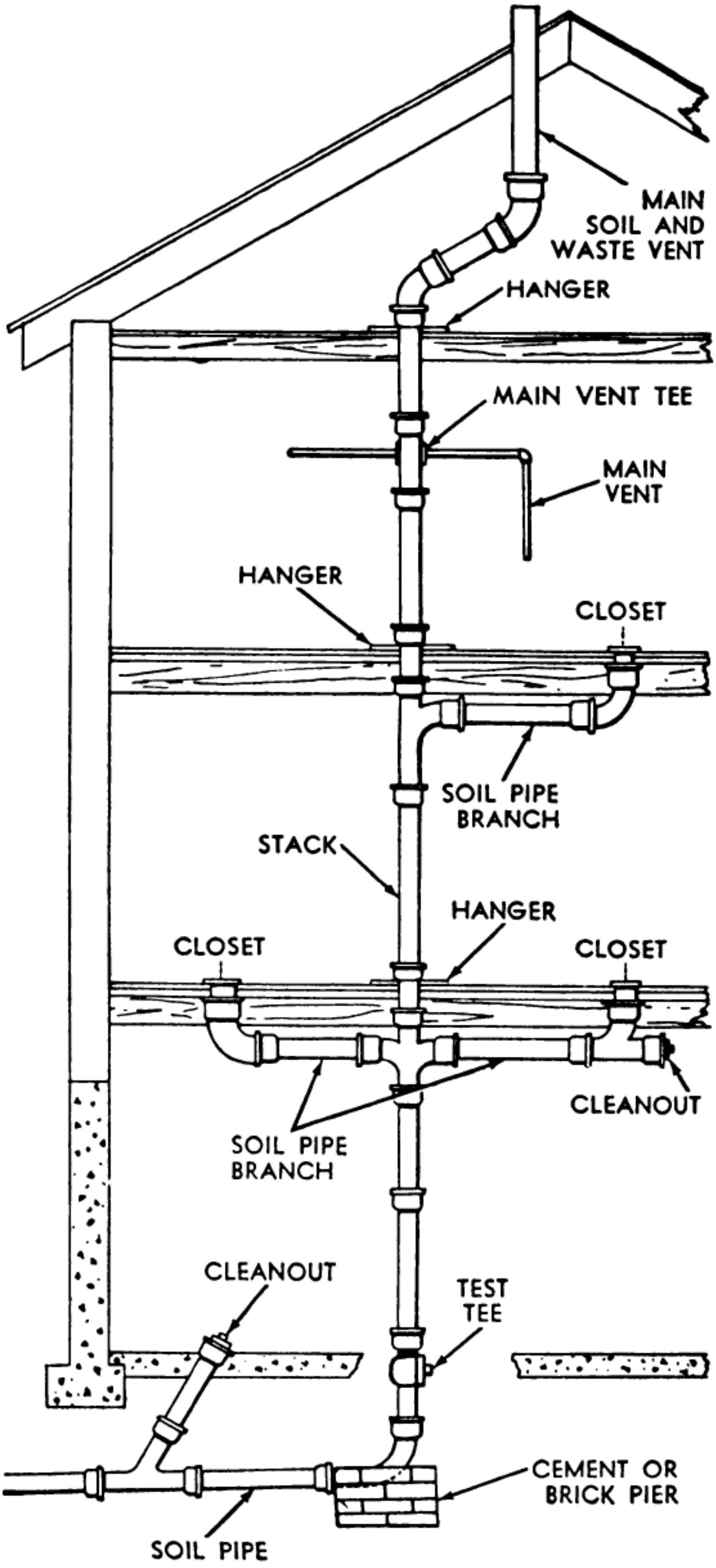


Figure 2–39.—Soil pipe branches.

TABLE 1

Distance of Fixture Trap From Vent

Size of fixture drain, inches	Distance from trap to vent	
	Feet	Inches
1¼	2	6
1½	3	6
2	5	0
3	6	0
4	10	0

TABLE 2

Size and Length of Main Vents

Diameter of soil or waste stack, inches	Fixture units connected	Diameter of vent required, inches					
		2	3	4	5	6	8
		Maximum length of vent, feet					
2	12	200					
2	20	150					
3	10	100	600				
3	30	60	500				
3	60	50	400				
4	100	35	260	1,000			
4	200	30	250	900			
4	500	20	180	700			
5	200	...	80	350	1,000		
5	500	...	70	300	900		
5	1,100	...	50	200	700		
6	350	...	50	200	400	1,300	
6	620	...	30	125	300	1,100	
6	960	...	24	100	250	1,000	
6	1,900	...	20	70	200	700	
8	600	...	...	50	150	500	1,300
8	1,400	...	...	40	100	400	1,200
8	2,200	...	...	30	80	350	1,100
8	3,600	...	...	25	60	250	800
10	1,000	...	...	...	75	125	1,000
10	2,500	...	...	...	50	100	500
10	3,800	...	...	...	30	80	350
10	5,600	...	...	...	25	60	250

takeoff from the vertical stack is by using a **Y**-branch with an 8th bend calked into it. Another method is by using a sanitary tee, which is an extra-short-pattern 90° **Y**-branch. Of these two methods, preference usually is given to the sanitary tee. The reason is that by using the sanitary tee you eliminate one fitting and an extra calked joint which are required for the 8th bend takeoff. We might add that under some local codes you may be permitted to connect more fixture units to a given size stack when a **Y**-branch and 8th bend is used. In such a case, the **Y**-branch and 8th bend may be more desirable than the sanitary tee. Once either fitting is calked into place, however, the horizontal branch can be extended as necessary with lengths of soil pipe. They, too, are joined by calking. Always make sure that the soil pipe is graded or sloped to ¼ inch per foot.

Waste pipes should be graded downward to ensure quick draining. Vents should be graded upward to safeguard against back flow.

LAYING WATER PIPE

The water main is the source of supply for the water distribution system. In climates where the ground freezes, the water main will require trenches deep enough to place the piping below the frost line. Pipe that runs across roads or areas of vehicle traffic must be buried in trenches about 4 feet deep.

Water pipe need not be sloped to provide flow. Flow is achieved by gravity or by using a pumping system. Where pipe must be placed in a sloping trench, the slope should be as even as possible to safeguard the pipe against bending and breaking.

Obviously, pipe aboveground that crosses deep gullies or rough ground must be supported to avoid bending and breaking. A rack similar to that illustrated in figure 2–40 will serve this purpose.

No given grade is required in the case of trenches for underground water pipe. But the bottom of the trench

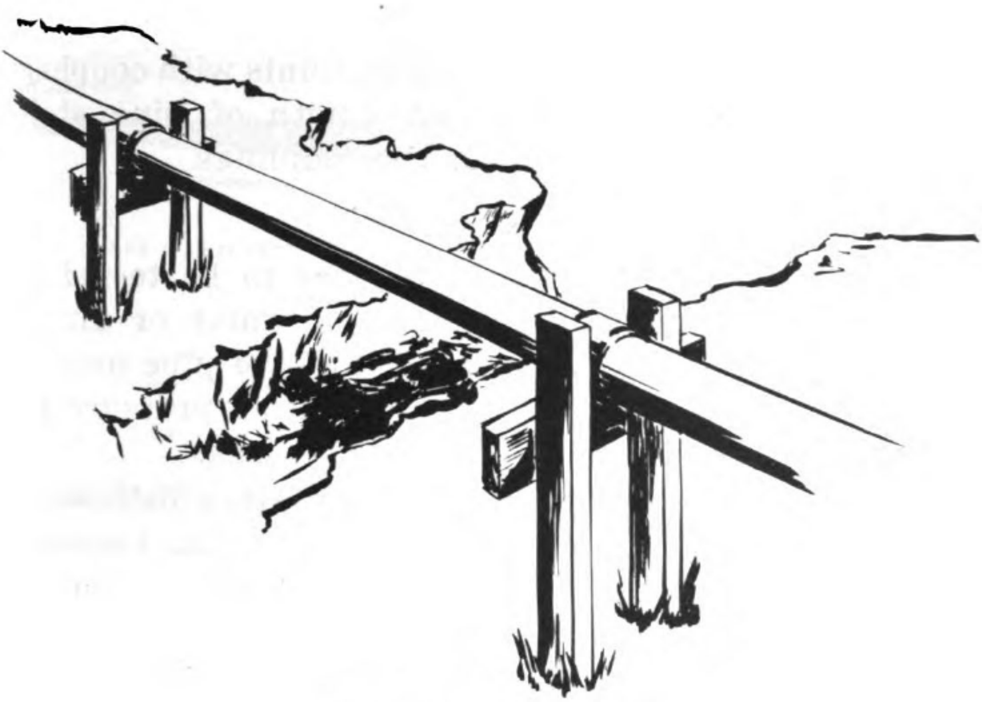


Figure 2–40.—Pipe rack.

should be smooth, as well as form an approximate straight line between connections. Make your trench about 2 feet wide, and while it is being dug, lay your pipe and couplings alongside it. (See fig. 2–41.)

Before you start placing the pipe, shut off the water

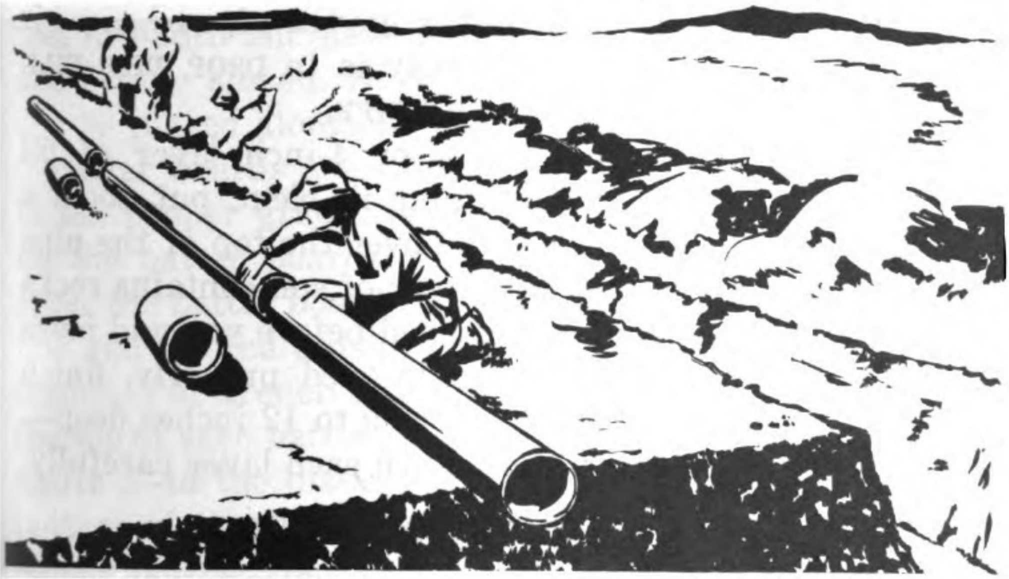


Figure 2–41.—As trench is being dug, place pipe and couplings alongside it.

in the main supply line. The placing should start at the main supply tee. Make your threaded joints with couplings and partially backfill over each length of pipe at its center. Be careful not to cover the couplings.

Testing

Of course, newly installed pipe has to be tested for leaks. This can be done by means of water or air. To make a water test, plug up the end of the pipe and run water into it. Let it stand under operating pressure for 4 to 8 hours and then inspect the pipe for leaks.

For an air test, cover all joints and fittings with soapy water. Then fill the line with compressed air. Leaks, if present, can be detected by bubbles formed by the escaping air.

If your inspection discloses a leak, you will have to make a new joint. If no leaks are found, you can now finish backfilling the trench.

Backfilling

You must exercise care in backfilling to keep the pipe straight and minimize settlement. Soil used to backfill around the pipe should be as free as possible from rocks and debris. Do not throw fill material directly on the exposed pipe, as this is likely to damage the pipe or move it out of alinement. The correct way is to DROP THE FILL MATERIAL ON EITHER SIDE OF THE PIPE.

In backfilling, throw in a 3- or 4-inch layer of fill material around the pipe and tamp it. Next, put about a 6- or 8-inch layer of fill material over the top of the pipe and tamp it down also. If this layer of soil contains rocks or debris, see that they are removed before you add more soil. After this layer has been tamped properly, finish filling the trench with layers about 9 to 12 inches deep—as many as needed—and tamp down each layer carefully.

LAYING SEWER AND DRAIN PIPE

Sloping trenches are necessary to produce flow in sewer and drain pipe. (See fig. 2–42.) Cast-iron or vitrified-tile

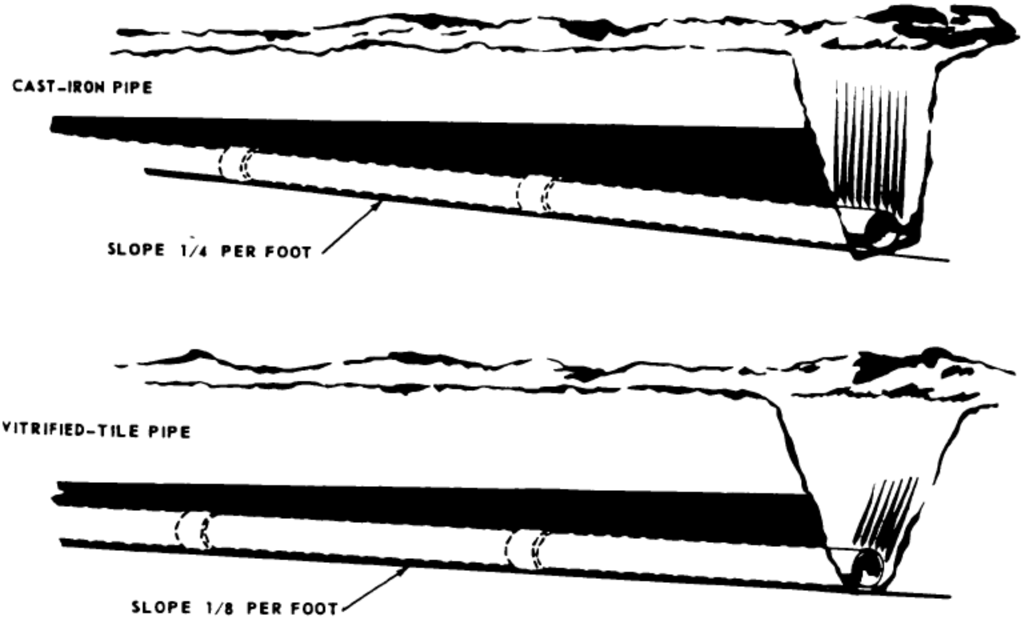


Figure 2–42.—Sewer and drain pipe must be sloped to maintain flow.

pipe should have a slope of not less than 1/8 inch per foot of run, with 1/4 inch per foot being preferable. Where the weather gets cold enough for freezing, the pipe must be installed below the frost line. Also, pipe that crosses roads or areas of vehicle travel must be buried in trenches about 4 feet deep.

Make your trenches for sewer and drain pipe about 2 feet in width and have the bottom of your trench smooth and evenly sloped. During the digging process, the pipe can be placed alongside the trench.

Batter boards are used as a guide in digging trenches to the proper grade. (See fig. 2–43.) The job of setting up the batter boards belongs to the Surveyor. He will space the batter boards at equal intervals along the trench line and set the tops of them to the desired grade of the trench. The trench is then dug to the same depth below the top of each batter board. For example, suppose that in figure 2–43 the distance from the top of board *A* to the bottom of the trench is 3 feet. In that case, the trench should be dug to give the same measurement at boards *B*, *C*, *D*, and *E*.

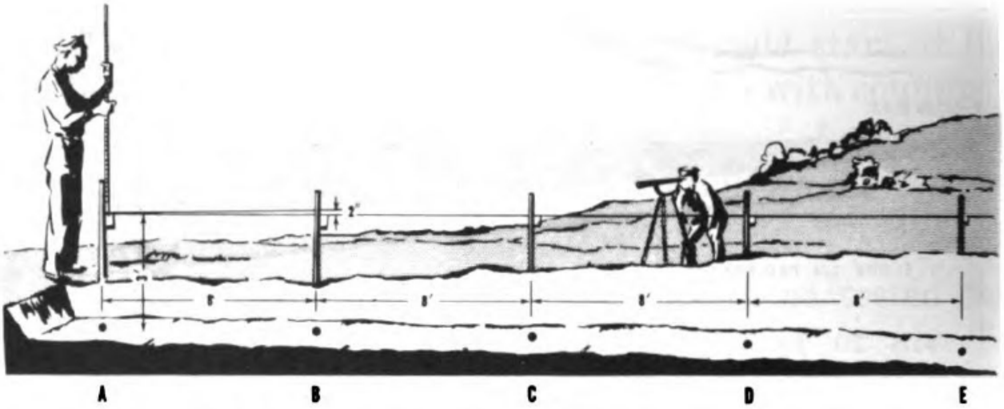


Figure 2–43.—Setting batter boards to ¼" per foot grade.

After the trench has been dug to the proper slope, place the pipe in it and make the necessary joints. Backfill the trench, following the procedure described for water pipe.

INSULATION

The purpose of insulation (or lagging) in plumbing is to prevent pipes from coming into contact with the outside atmosphere. Insulation is sometimes needed for both hot- and cold-water pipes. Suppose you have a hot-water line in which the water has to travel a considerable distance before reaching the fixtures from which it is to be drawn for use. If the pipes through which the hot water travels are uninsulated the water will get cold before it reaches the fixtures. In the case of cold-water pipes, insulation not only will keep water cold but will prevent condensation on the outside of the pipe. Condensation can result in damage to a building by dripping from pipes onto walls, floors, or ceilings.

There are various types of lagging (insulation) materials, including asbestos, cork, felt, glass, magnesia, mineral, rockwool, foil, and tar paper. The type used must be determined by the specific need of the job at hand. However, the principles of all insulating jobs are basically the same.

One of the most used types of insulation is known as 85 percent magnesium. This type is very suitable for

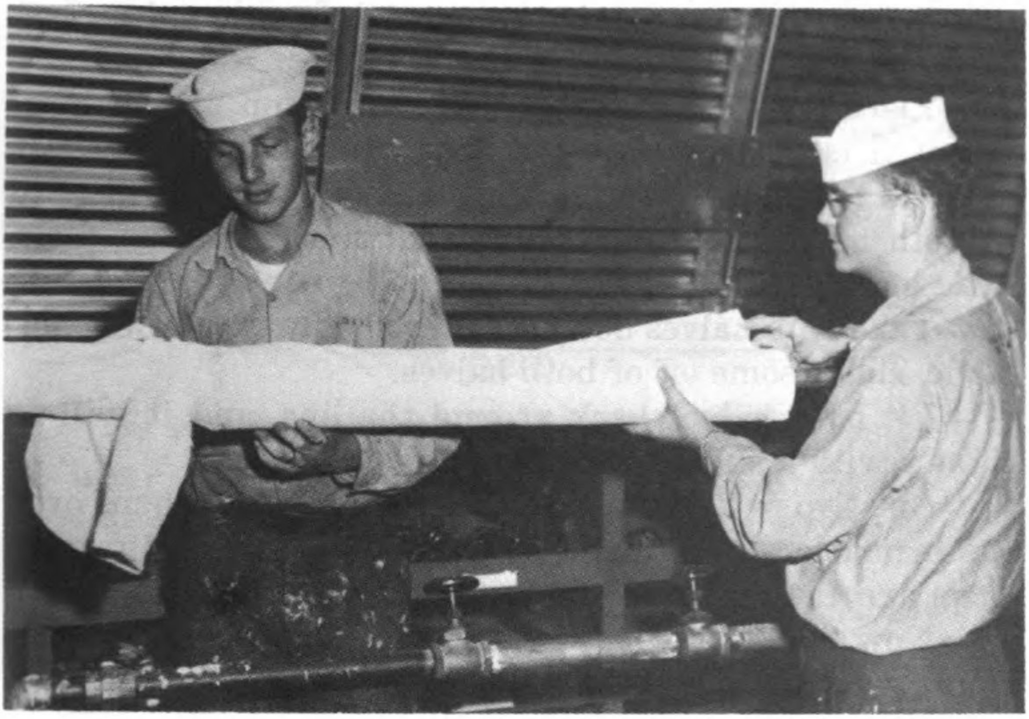


Figure 2–44.—Pipe lagging.

steam- and hot-water lines, and can be used on other pipes where the temperature does not exceed 600° F. (For higher temperatures there is an asbestos-sponge felt insulation—like that used on exhaust lines of diesel engines.) The 85 percent magnesium comes in three different forms: molded, powdered, and blocked. Each is designed for a different purpose. The MOLDED type is used on pipes of various sizes. It comes in 3 foot lengths. Available pipe sizes range from ½ inch to 12 inches in diameter. The BLOCK type is suitable for boilers or other places where you have a large flat surface to cover. It is available in various-sized blocks. The POWDERED type, when mixed with water to form a paste, is used as a covering for fittings, valves, and the like.

Insulating With Magnesium

When the insulation to be applied is the molded form of magnesium material, here is the procedure to follow.

—Select the proper-sized material for the pipe, and turn the muslin back as required.

—Place one-half of the insulation on top of the pipeline if it is horizontal to the floor, and fit the other half to it. If the line is vertical to the floor, you will have to fit both halves around it. Note that the insulation fits a little loosely.

—Take both halves down, then with any type of cutting blade, shave some off of both halves.

—Fit both halves back around the line, and it will fit tightly with a slight gap on each side.

—Cut two or three pieces of wire and wrap them over the insulation, or if using clamps, take two or three of them and fasten the insulation securely to the line.

—Now take some of the scrap pieces, crush them with your hands and mix with water. Smooth the mixture over the cracks or gaps in the insulation to completely seal and insulate the line.

—Dip the muslin that was removed from the insulation in a flour and water paste and pull tightly around the completed job to hold it securely and protect the insulation. Apply the muslin diagonally to ensure a tighter and neater job.

The procedure for insulating with the powdered form of magnesium involves mixing the powder with water to form a mud-like substance of thick consistency. This mixture is then applied with a trowel to the fitting or valve to be insulated.

The method commonly used to insulate fittings consists of first applying a coat of the mud-like mixture, then filling in with small chunks of asbestos. Follow with a second coat of the mixture, building it up even with the rest of the pipe. Now add a covering of canvas—and the fitting is insulated.

Hair Felt and Tar Paper

Hair felt and tar paper provide an excellent insulation for cold-water lines. In applying this type of insulation, first wrap a layer of tar paper around the pipe, then follow with a layer of hair felt, tying each layer separately with any type of string or cord. Repeat this operation until you have three layers of felt and four layers of tar paper. Complete the operation by adding a layer of waterproof paper.

QUIZ

1. What is plumbing?
2. What are the four principal kinds of pipe used for sewers and drains to make up that part of the plumbing system installed belowground?
3. What happens if vitrified clay pipe is laid in unstable soil?
4. What is the standard length of asbestos-cement pipe?
5. Why must lead pipe be well supported?
6. What are bushings?
7. What type of wrench would you use on hexagonal nuts, valves, and fittings?
8. When is it of particular advantage to use the three-wheel cutter rather than the wheel-and-roll cutter?
9. Why is reaming necessary?
10. What is the purpose of filling a copper pipe with sand before bending?
11. To what does the term "roughing-in" refer?
12. Name the two types of check valve.
13. What are the five different methods commonly used in measuring pipe?
14. How are joints generally made in cast-iron soil pipe?
15. What type of joints are commonly used on galvanized steel and galvanized wrought-iron pipe?
16. Of what does the butt joint consist?
17. How is copper tubing usually joined?
18. Why should hangers be installed for overhead pipework?
19. How is flow achieved in a water pipeline?
20. How wide should you make trenches for sewer and drain pipe?

21. What is the purpose of insulation?

22. In making a poured-lead joint in cast-iron soil pipe, what precaution should be taken if lead must be poured into a wet hub?

23. To what does the term "trap seal" refer?

24. Where are vents for water closets connected?

25. What is a main vent?

26. For what purpose is a unit vent used?

27. What are soil pipe branches?

28. What is the maximum number of fixtures that can be put on a single circuit vent?

29. In which position, vertical or horizontal, is the main soil and waste stack installed?

CHAPTER 3

PLUMBING REPAIRS

Prompt attention should be given the matter of repairs and adjustments which are needed from time to time in the plumbing system. Fixing leaky faucets, unstopping clogged sewer lines, and thawing frozen pipes are only some of the jobs that become necessary through failures in a fixture or other part of the plumbing system.

To become a good plumber it will be to your advantage to know the principle on which various plumbing fixtures work. This knowledge will be an asset when something goes wrong with a fixture and it is up to you to locate the source of trouble and get the fixture back in proper operating order. For instance, if you understand how a compression faucet works, you know that a continuous drip is an indication that (1) the seat washer is worn out or swollen, or (2) the valve seat has become scored. It is possible, of course, for a faucet to have both these defects at the same time.

There is a lot to know about plumbing repairs and adjustments. Keep in mind, therefore, that the subject is only covered in part in this chapter. Use the information given here as a foundation on which to build a wider and broader knowledge of the repair and servicing phase of the plumbing trade. Familiarize yourself with the tools and procedures discussed, and don't fail to put into practice what you learn.

COMPRESSION FAUCET

One type of faucet commonly in use is the COMPRESSION FAUCET, a cut-away of which is shown in figure 3–1. Before discussing repairs to this faucet, let us explain briefly what happens when the faucet is turned on and when it is turned off.

Using figure 3–1 to help you visualize the operation, note that when the HANDLE is turned to the left the STEM rises to lift the WASHER from the VALVE SEAT, allowing the water to pass.

Now note that when the HANDLE is turned to the right, the STEM is lowered and presses the WASHER against the VALVE SEAT, cutting off the flow of water.

Fixing a Leaky Faucet

A small, steady leak in a faucet can waste an enormous amount of water. From the standpoint of economy, therefore, a faucet suffering from "driposis" should be fixed promptly.

Leaks are caused frequently by a WORN OUT SEAT WASHER, which is located at the end of the valve stem. (See fig. 3–1.) With a little experience, the plumber-trainee should be able to replace this washer in a few minutes.

To replace the seat washer on a compression-type faucet, first turn off the water supply to the faucet and open the faucet all the way. With a monkey wrench, unscrew the packing nut located at the top of the faucet body. (If a monkey wrench is not available, use an ordinary adjustable wrench.) Turn the faucet handle to the left and remove the valve STEM from the faucet body.

Next, remove the small brass screw by which the washer is held in place at the end of the stem. Take off the old washer and insert a new one of the same size. Replace the small brass screw (if corroded or damaged, put in a new one). Now replace the stem in the faucet and screw the packing nut back into position.

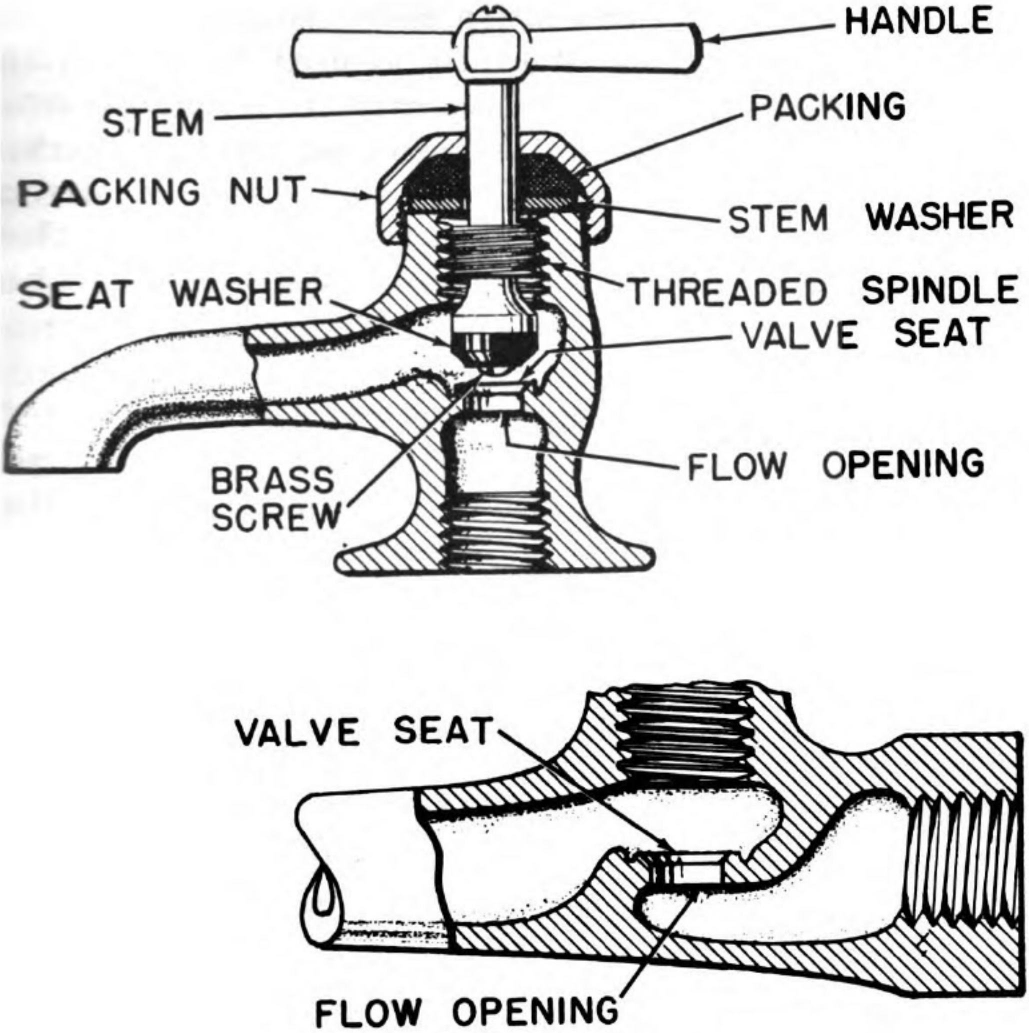


Figure 3–1.—Compression faucet.

When a new washer fails to stop a leak, the trouble is a SCORED VALVE SEAT. This condition is caused by gritty matter in the water. One remedy for a scored valve seat involves refacing the seat. The tool used for the refacing operation is a VALVE RESEATER. Its design includes a handle similar to that of a faucet at its upper end, and a reaming or dressing device at its lower end. Make sure you always follow the directions furnished with the reseater. In general, you can expect the procedure to consist primarily of removing the valve stem and replacing with the reseater, then turning the handle to obtain the desired cutting action on the damaged seat.

A special type of composition sleeve is now available for reseating purposes. When it is used the refacing process just described is not necessary. To install a composition sleeve, insert it in the faucet seat. Then remove the washer and screw from the end of the spindle, since they are not required when the sleeve is used. When the faucet is closed, the recessed surface at the end of the spindle bears against the rounded surface of the composition sleeve to prevent leaking.

At times you will probably be called on to fix a faucet which leaks around the handle or packing nut when the faucet is turned on. When this occurs, check to see if the trouble is a loose packing nut. If the nut is on watertight, then you will have to remove it and replace the PACKING (or STEM) WASHER inside. (See fig. 3–1.) Remove the handle and packing nut ONLY in replacing this washer—NOT the valve stem as when replacing a seat washer.

PIPE LEAKS

When a leak develops at a threaded joint of pipe, one of the most likely suspects is a fractured or ruptured pipe. Fractures often occur at the end of a pipe length owing to strain imposed by vibration of water hammer. But why the end of the pipe? That is because the wall thickness is decreased and weakened by threading. The risk of fracture becomes even greater when the threads are not cut true. In cold climates, freezing sometimes causes pipes to rupture, in which case replacement becomes necessary. A loose or cracked fitting can also cause leakage at the threaded joint of a pipe. These and other common failures which result in leakage in pipes make it important that you always determine the exact location and cause of failure before commencing any repairs to the piping.

Stopping Flow Through Pipe

The best cure for a fractured or ruptured pipe is replacement with a new section. The first step of the repair procedure consists of shutting off the flow of water and draining the pipe. This involves no problem when you have a shut-off valve in good working order ahead of the point to be repaired, because all you need do is close the valve. In case you have no shut-off valve nearby, or have one that doesn't work properly, the next best thing to do would be to close down the line for a short time—if possible. Without trying to sound too difficult, let us suppose you have a situation where it is hardly possible to close down the line long enough to make the necessary repair. What then? At this point, about the simplest solution to the problem would be to shut-off the flow of water by freezing the pipe.

When the piping to be repaired is covered, you must expose about 15 inches of the piping and box it in before starting the freezing operation. After that, all you need to do is pack the box with ice mixed with rock or coarse salt. This mixture causes the water inside the pipe to freeze and halt the flow. You can figure, ordinarily, on needing about 40 to 50 pounds of ice.

For good results in freezing, use one of the following mixtures:

(a) Two parts of crushed ice to one part of salt, with an equivalent temperature of —5° F.

(b) Five parts of crushed ice, two parts of salt, and one part of ammonium chloride; equivalent temperature —12° F.

(c) Five parts of crushed ice, two parts of salt, and one part potassium nitrate; equivalent temperature —18° F.

Replacement Procedure

When a union is available to permit unscrewing a leaky section of pipe, only one length of new pipe will be needed for the replacement. At times, you may not be fortunate enough to have a union located nearby. In that case, it will be necessary to cut the pipe with a hacksaw, and then to unscrew the cut ends. In doing this, make sure you cut the pipe not less than 4 inches from a fitting. When the old section is disconnected by cutting, two sections of pipe and a union will be needed for the new section. When assembled, the over-all length should equal that of the old section.

Emergency Repair

In this plumbing business you may occasionally have a pipe start leaking but find that the proper materials needed to repair it permanently are not readily available. The answer is to use a temporary, or emergency, type

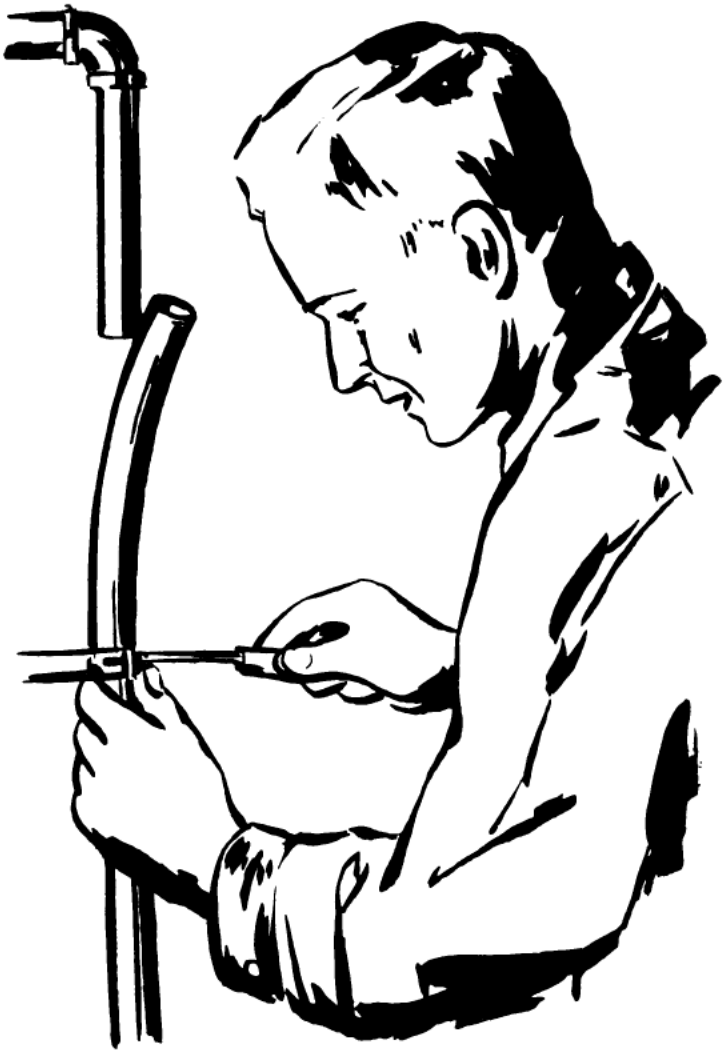


Figure 3-2.—Emergency repair of leaky pipe using a length of hose.

repair. Emergency repairs are likely to become necessary in the best of organizations. Bear in mind, however, that a permanent-type repair should always be made just as soon as the tools or materials needed for it become available.

One simple method of repairing a leaky pipe temporarily involves using a length of rubber hose. After turning off the water supply, remove the defective section of pipe by cutting with a hacksaw. Then take a piece of rubber hose, slightly longer in length than the section of pipe you removed and slip it over the ends where the cut was made, as illustrated in figure 3–2. Make sure the inside diameter of the hose is the same as the outside diameter of the pipe. Hose clamps can be used to hold the hose securely in place.

Another temporary measure consists of wrapping electrician's friction tape tightly around the pipe, having it extend about 2 inches above and below the leak.

WATER-TANK FAILURES

Where a plumbing system has been in use for some time, two failures in water tanks which should come as no surprise are (1) leaky seams, and (2) corroded areas requiring welded patch plates.

To repair a defective seam, first drain the water tank dry. Then clean the surfaces to be repaired until they are bright. By welding or brazing, the leaky portions can then be made watertight.

An effective tank patch for a large hole can be provided without draining the tank or service outage. You will need both a temporary and permanent type patch. The temporary patch is a softwood plug. It should be inserted in the hole, and tapped lightly with a hammer until the seal is watertight. Then saw off the end of the plug so that it will be flush with the tank wall.

Next, the area around the hole which will be covered by the permanent patch should be cleaned by wire brushing. With that done you are ready to apply the permanent patch, which consists of a rubber gasket and a metal plate. For a gasket, use rubber sheeting. Make sure the piece of sheeting used is at least 6 inches by 6 inches and 1/16 inch thick. Center the sheeting on the plug and use adhesive to hold the sheeting in place on the tank wall.

The patch plate, of the black steel or nonferrous metal type, must be of the same material and thickness as the tank wall. It should also be slightly larger in size than the gasket. Place the metal plate over the rubber gasket, positioning it to give an equal overlap around the edges. To complete the operation, braze or weld the plate to the tank, using a continuous seam.

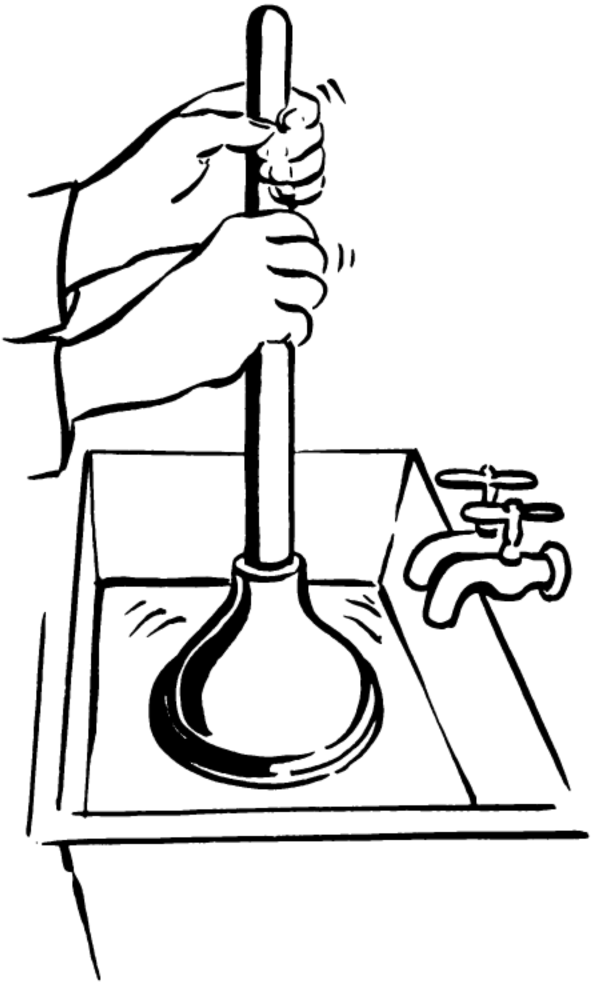


Figure 3–3.—Using force cup.

CLEARING STOPPAGES

The FORCE CUP (or "Plumber's Friend") is the simplest tool for clearing stoppages. This familiar tool (see fig. 3–3) has a stiff, rubber, bell-shaped cup about 5 inches in diameter, fastened to a wooden handle.

In using the force cup, partly fill the fixture with water and place the cup over the fixture opening. Simply work the handle up and down to create alternate compression and suction to dislodge the obstruction.

Another common method used to unstop ordinary

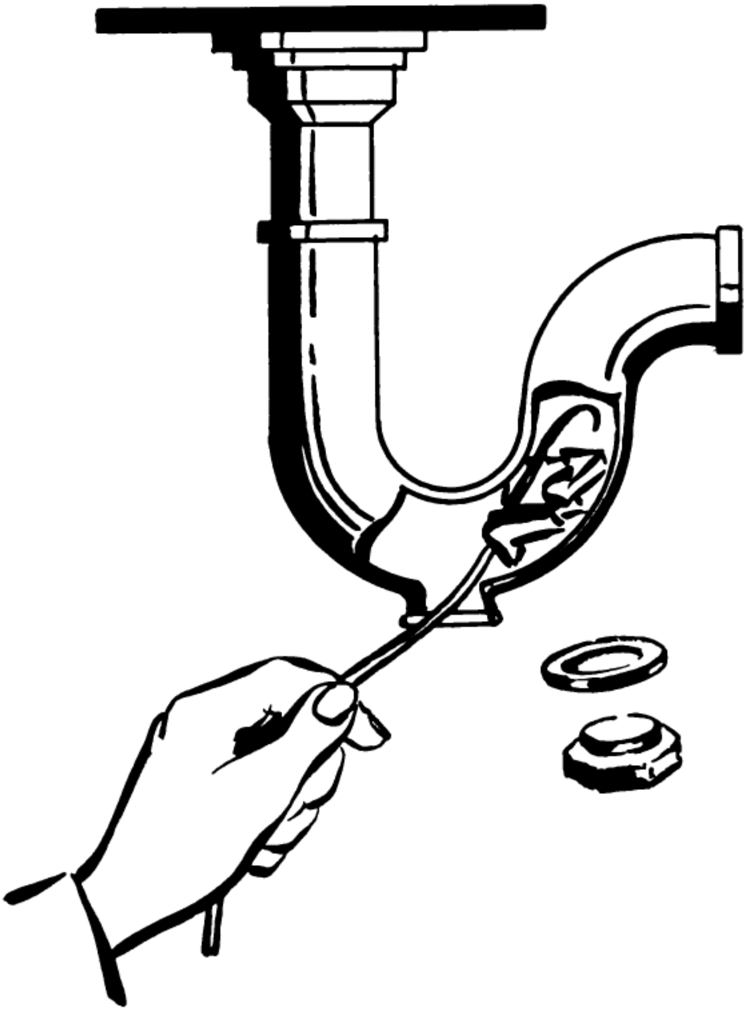


Figure 3–4.—Cleaning out a trap.

fixture traps is as follows: (1) open the clean-out plug on the trap (see fig. 3–4); (2) loosen and remove the obstruction with a bent wire; (3) flush with hot water.

You will find **FLEXIBLE-COIL WIRE AUGERS** effective devices for removing obstructions such as newspapers, rags, garbage, and toilet articles from traps, sewers, and drains. Augers are available in various lengths and sizes. In figure 3–5, the auger at A is 4 feet long and has a small steel cable extending from the handle to the wire hooks. To avoid unnecessary trouble when inserting this auger into a trap, draw the wire hooks into the coil.

The auger shown at B, figure 3–5, is 8 feet long and has a crank handle and corkscrew point. It is an advantage to have two men operate this auger. One man turns

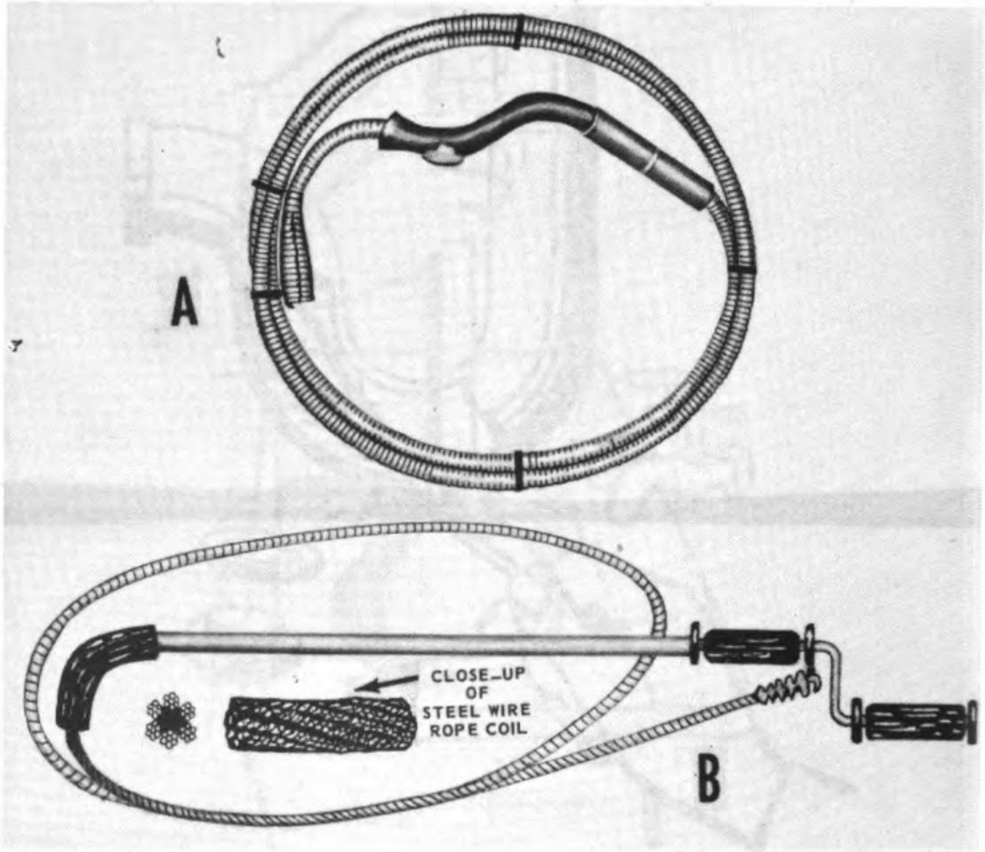


Figure 3–5.—Coil-spring steel augers for removing obstructions from drains.

the handle while the other man guides the cable and keeps the spring in line. After the obstruction is reached, make sure you screw in the corkscrew before attempting removal.

The closet auger shown in figure 3–6 is a good tool to use when a closet bowl is so clogged up that it can not be cleared with a force cup. It is a simple tool to operate.

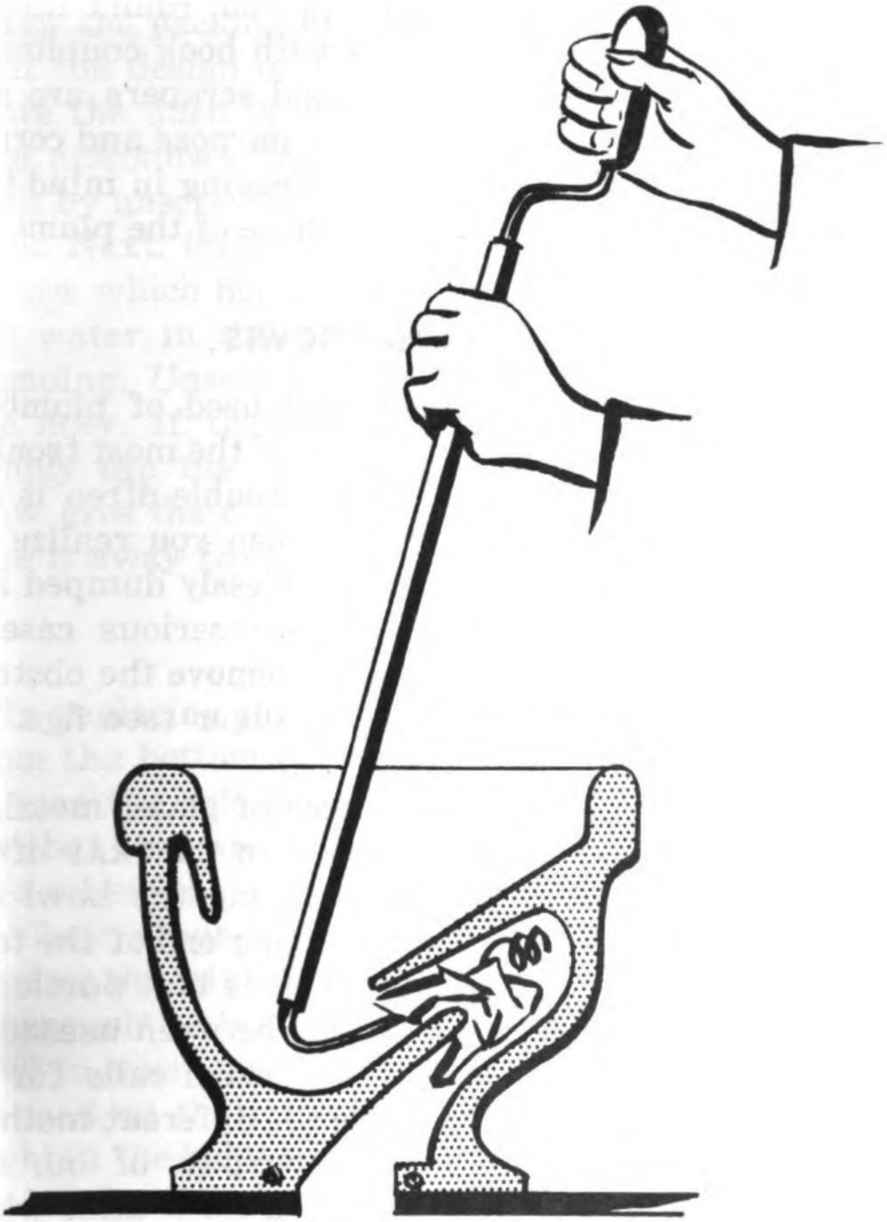


Figure 3–6.—Using closet auger.

Simply push the auger into the closet until the end strikes the obstruction. Then crank the handle until the auger screws into the obstruction and remove. After removal, clean the closet with hot water and potash.

Flat steel sewer rods, equipped with either an oval or revolving spear point and an automatic grip handle, provide another good means of removing obstructions from traps, sewers, and drains. These rods are available in various lengths and widths.

In addition to the tools already named, round wooden sewer rods (in 3 or 4 foot lengths with hook couplings), wire sewer brushes, root cutters, and scrapers are also used in clearing stoppages. Learn the purpose and correct method of using each clean-cut tool, keeping in mind that clearing stoppages is an important phase of the plumber's job.

SERVICING CLOSET BOWLS

The flush toilet is one of the most used of plumbing fixtures, and you will likely find it one of the most troublesome. When it gets out of order the trouble often is due to clogging. That is not surprising when you realize the million-and-one objects which are carelessly dumped into closet bowls. Unless you have a very serious case of clogging, you will probably be able to remove the obstruction with either a force cup or closet auger (see figs. 3–3 and 3–6).

It is possible, of course, for a piece of glass, metal, or other such object to become so lodged in the TRAP of the bowl that fixing it will require removing the bowl and forcing out the obstruction from the other end of the trap. Speaking of the trap, remember that it is that portion of the closet bowl in which water stands between uses.

Now suppose that you have a job which calls for removal of the closet bowl. Since there are different methods of flushing, let us assume, for the purpose of our discussion, that flushing is by means of a flush tank which is mounted on the wall behind the closet bowl.

Removing Closet Bowl

When removal of the closet bowl becomes necessary, always secure the main water supply prior to breaking any other supply line.

A PLATED ELBOW often provides the means by which the closet bowl is connected to the flush tank. This is an advantage because the flush tank, being a separate unit, does not have to be removed in order to remove the bowl. You do have to remove the elbow, however. To do this, unscrew the packing nut at the tank and at the bowl.

If the design of the fixture makes it necessary to remove the flush tank in order to remove the closet bowl, first disconnect the water supply from the tank. This is done by unscrewing the union nut located underneath the tank. Next, flush the tank to empty it; then remove the screws which hold it to the wall. With that done, remove the water in the trap of the closet bowl by bailing or pumping. Unscrew the nuts used to fasten the bowl to the floor. If these nuts are covered by porcelain caps, simply tap the cap lightly with a mallet to remove it. Now give the closet bowl a little jar with the hand and ease it away from the floor.

Replacing Closet Bowl

In replacing the closet bowl, clean off all the old putty from the bottom of the bowl and from the closet flange. In case the hold-down bolts are badly worn or corroded, see that they are replaced. Also, make sure that the floor area where the bowl is to be placed is clean and dry.

Allow about 3 pounds of bowl-setting putty for replacing the joint between the bowl and floor. Apply putty generously to the bottom of the bowl and then place the bowl in position. Bear in mind that the putty should not be used on the joint between the closet and waste pipe. Tighten the hold-down nuts the amount necessary to have the bowl set level on the floor. With a putty knife, remove the excess putty from the joint.

NOTE: Where a gasket (instead of putty) is used for the connection, inspect the old gasket carefully. If defects are noted, replace the old gasket with a new one. Always make sure, too, that the contacting surfaces of the gasket are thoroughly clean.

If the flush tank and elbow have been removed, replace these parts next. With that done, replace the union nut that goes underneath the tank, and turn on the water.

FLUSH TANK

You will find it an advantage to know the basic principle on which the flush tank operates. This will help you in locating the source of trouble when a tank gets out of order. Therefore, before we take up the repair phase of the flush tank, let us discuss briefly what goes on inside this mechanism during the process of flushing. For clarity, refer to figure 3–7 as we go along, keeping in mind that in different types of flush tanks you may find some variation in the method of operation.

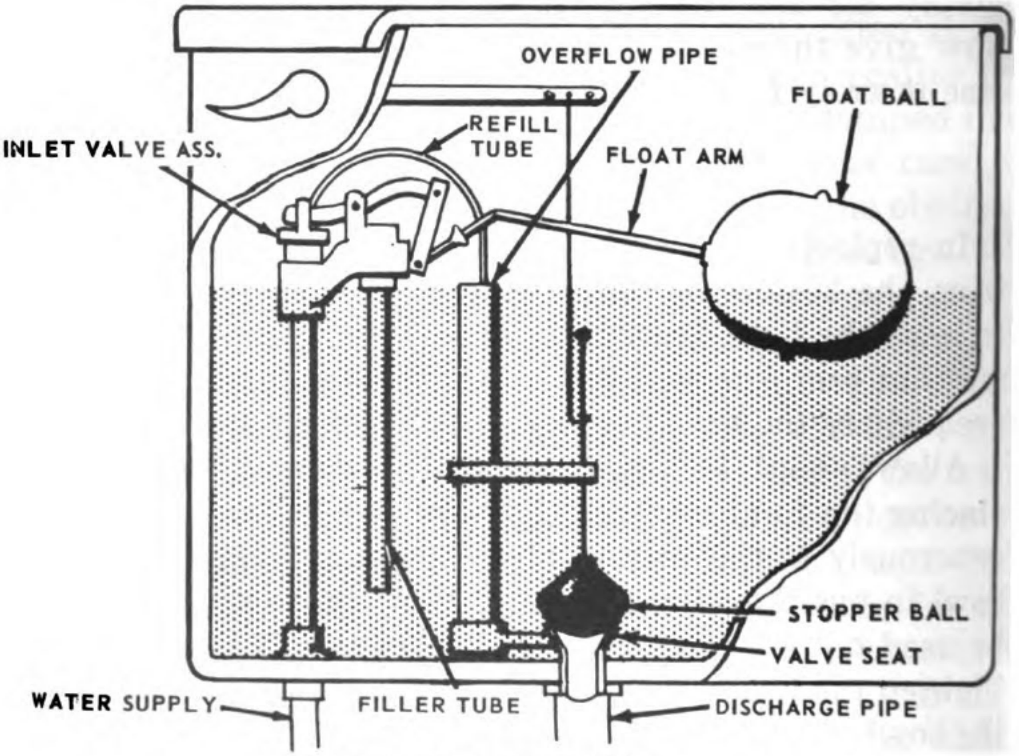


Figure 3–7.—Flush tank.

When you trip the lever outside the flush tank the rubber STOPPER BALL is raised from the VALVE SEAT to release water into the closet bowl. During this emptying process, the FLOAT BALL moves downward as the water level recedes. Movement of the FLOAT ARM causes a plunger in the INLET VALVE ASSEMBLY to open and a new supply of water is admitted through the SUPPLY PIPE. The stopper ball seats as the water flows from the tank; incoming water helps to hold the ball in position. Hence, the new supply of water is held for the next flushing. As the water level rises during refilling, the FLOAT BALL also rises with it. The buoyance of the float ball provides the force needed to lower the plunger (see fig. 3–8) to shut off the water as the tank fills.

In figure 3–7 notice that there is a small REFILL TUBE which feeds into the OVERFLOW PIPE. During the refilling process, water passes through this tube and into the OVERFLOW PIPE, and thence to the closet water trap. Purpose of the refill tube is to ensure replacement of water in the trap. It is essential that this water be replaced as a safeguard to keep sewer gases from coming through the waste pipe.

Repairs

When water continues to run into the closet bowl after the flush tank is full, the trouble is in some part of the inlet valve assembly. As you can see—if you understand the details of operation given above—the plunger has failed to close the inlet valve as it should, and thus the excess water which continues to flow in (after the tank has reached the proper level) is being discharged through the overflow pipe and into the bowl. In checking for the source of trouble, here are the defects to look for: a leak in the float ball, a bent float arm, a worn washer on the bottom of the plunger, or a worn valve seat.

A good place to start is with the float ball, keeping in mind that a leaky, water-logged float will prevent the plunger from closing properly. A small leak in a copper

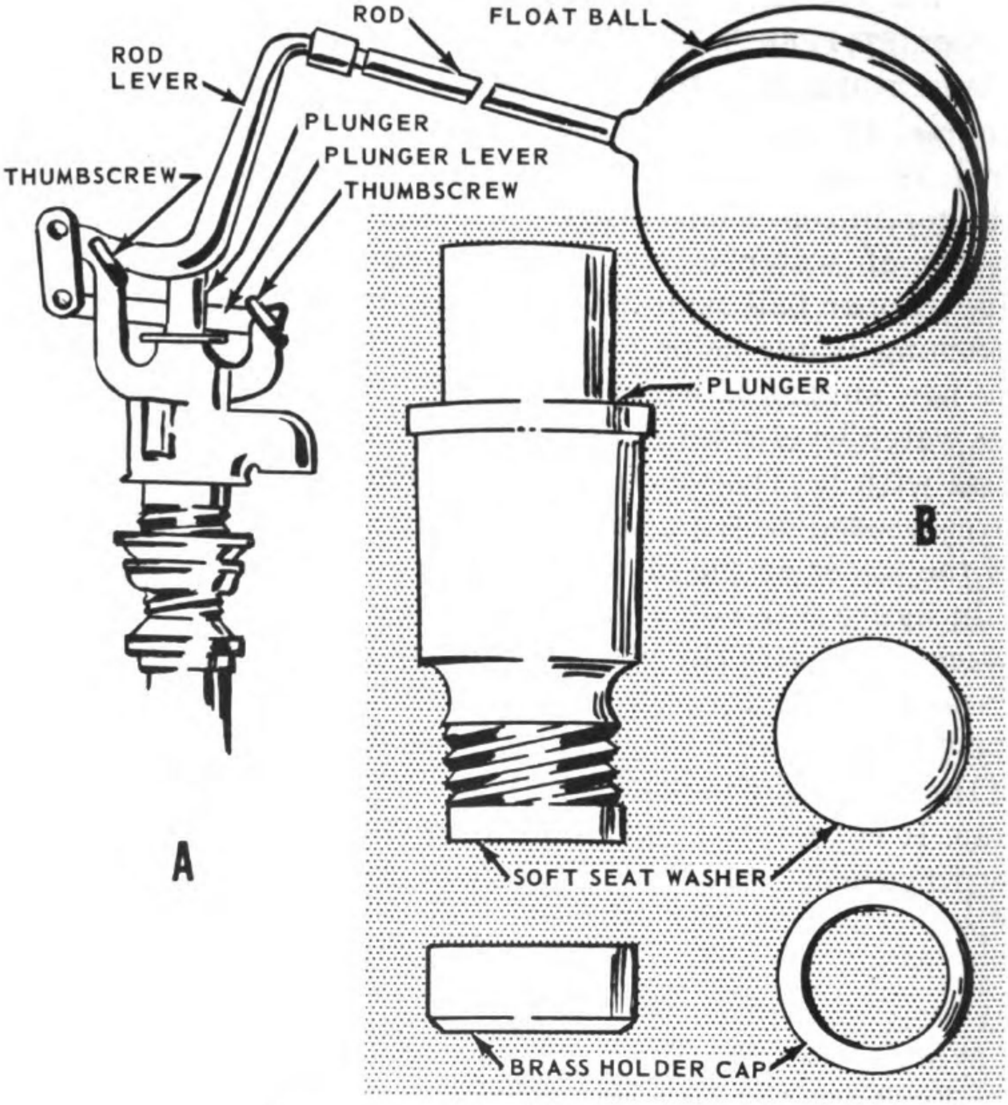


Figure 3–8.—(A) Ball cock (assembled)
(B) Plunger, washer, and cap

float can be remedied by soldering. If it is a large leak, though, simply replace the float with a new one. A damaged float arm should also be replaced with a new one. Sometimes you may find that the float arm is only bent or not allowing the valve to close far enough. In this case, the remedy is to bend the float end downward a bit, the purpose being to push the valve tighter into its seat.

When necessary to replace the washer on the bottom of the plunger (see part B, fig. 3–8), start by shutting off the water. Then unscrew the two thumbscrews that pivot the float-rod lever and the plunger lever (see part A, fig. 3-8). Push the two levers to the left, drawing the plunger lever through the head of the plunger. Now lift out the plunger, unscrew the cap on the bottom, insert the new washer, and reassemble the parts. If the cap is badly corroded, replace with a new one. In replacing the washer, examine the seat for nicks and grit, which, if present, may necessitate regrinding.

To consider another common disorder, suppose that water continues to run into the closet bowl after flushing, yet the tank does not refill. This indicates that some part of the FLUSH VALVE assembly is at fault, the result being that the flush valve is not closing properly. To locate the trouble and get the tank back in proper working order proceed as follows:

First, stop the inflow to the tank by holding up the float ball or supporting it with a stick. Then drain the tank by raising the rubber stopper ball. (See fig. 3–9.) Now examine the stopper ball to see if it is worn, out of shape, or has lost its elasticity. If either condition exists, unscrew the lower lift wire from the ball and replace the ball with a new one. See that the lift wires are straight and plumb. The lower lift wire is easily fitted over the center of the valve by means of the adjustable guide holder. By loosening the thumbscrew you can raise, lower, or rotate the holder about the overflow tube (see fig. 3–9). The horizontal position of the guide is fixed exactly over the center of the valve by loosening the lock nut and turning the guide screw. These adjustments are very important!

The upper lift wire should loop into the lever armhole nearest to a vertical from the center of the valve. A tank should empty within 10 seconds. Owing to lengthening of the rubber ball and insufficient rise from its seat, the time may be longer than 10 seconds and the flush correspondingly weak. This may be overcome by shortening the loop in the upper lift wire. A drop or two of lubricat-

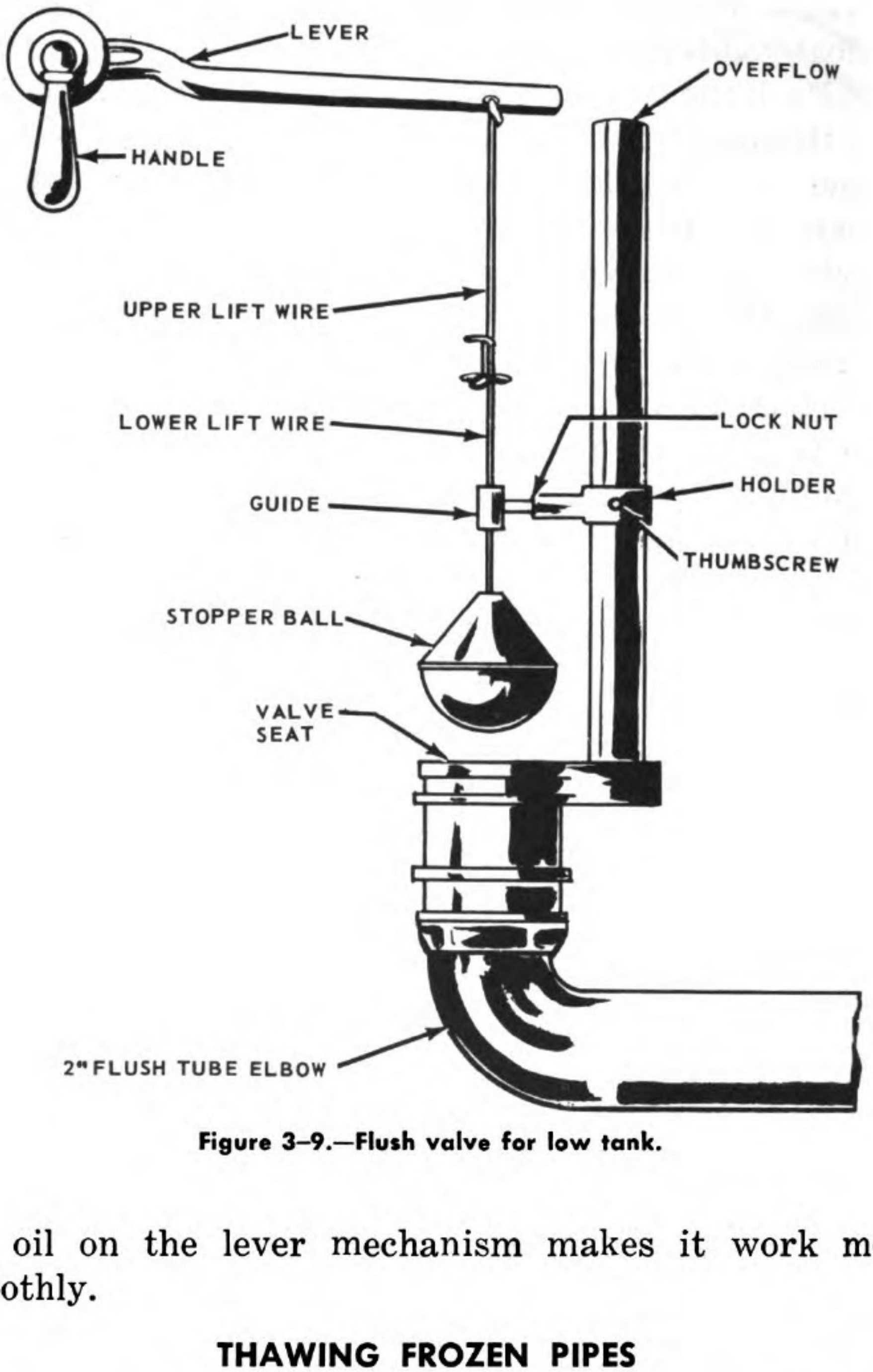


Figure 3–9.—Flush valve for low tank.

ing oil on the lever mechanism makes it work more smoothly.

THAWING FROZEN PIPES

In freezing temperatures the services of a UT will likely be needed at times to thaw out frozen pipes. Here are a few simple methods of doing the job.

Frozen pipes can be thawed by applying heat at one end of the frozen section. Do NOT apply heat at the middle of a frozen section. Reason: Expansion of heated water will burst the pipe! Before starting to thaw a frozen pipe, open faucets affected by the freeze.

Where there is no danger of fire, satisfactory results may be obtained simply by heating the pipe with a blowtorch—playing the flame on the outside of the pipe. Instead of a blowtorch, a burning newspaper or candle also may be used in this same manner.

Another method for exposed pipe is to wrap rags around the pipe, then pour on boiling water or apply steam. Repeat this operation in sections until water starts flowing from the open faucets.

A good method of thawing water pipes which are underground or otherwise inaccessible is indicated in figure 3–10. In using this method, remove the fittings

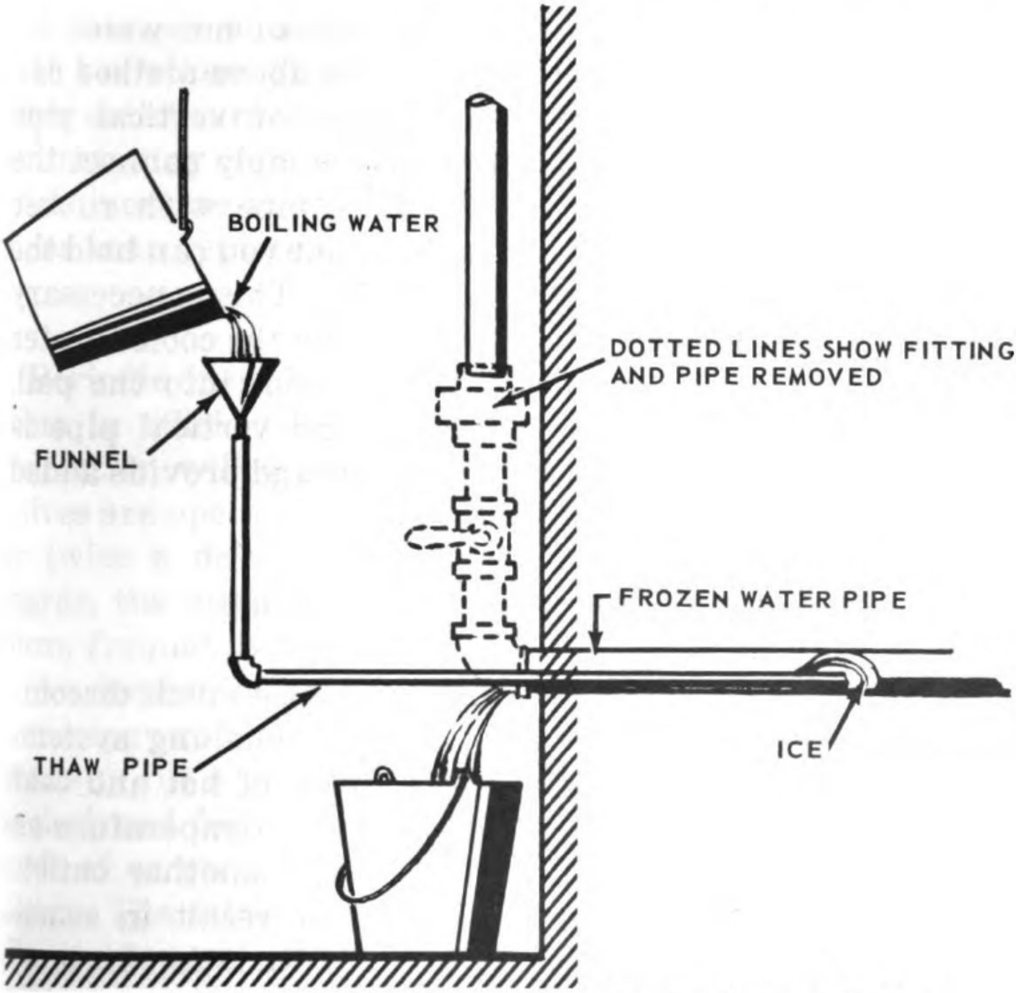


Figure 3–10.—Thawing an underground or otherwise inaccessible pipe.

(see illustration) and insert one end of a small pipe (a tube also will do) in the frozen pipe. Now add an elbow and piece of vertical pipe to the outer end of the thaw pipe. Place a bucket under the opening to the frozen pipe and insert a funnel in the open end of the vertical pipe (see fig. 3–10). With that done, start pouring boiling water through the funnel and into the pipe. As the ice melts push the thaw pipe forward. Where necessary, additional pipe can be added at the outer end until a passage is made through the ice.

Withdraw the thaw pipe quickly after the flow starts and do not stop the flow until the thaw pipe is fully removed and the pipe cleared of ice.

Instead of a funnel, a small force pump may be used. You will find it useful for thawing a long piece of pipe. If available, you can use steam in place of hot water.

We might point out further, that the above method can be used without the elbow and piece of vertical pipe shown in figure 3–10. In such a case, simply connect the funnel to the outer end of the thaw pipe with rubber tubing. Have the tubing long enough that you can hold the funnel above the level of the frozen pipe. This is necessary to give the hot water a head, thus forcing the cooled water back to the opening where it will run out into the pail. Hence, the advantage of the elbow and vertical pipe is that they increase the head of the water and provide added convenience when using the funnel.

VARIATION OF WATER PRESSURE

A variation of water pressure can cause much discomfort on the part of persons using the plumbing system. This trouble is what causes the mixture of hot and cold water from a shower to suddenly vary in temperature or rate of flow when water is turned on at another outlet. Failure to remedy this condition might result in somebody getting injured, especially if the variation in temperature is to the scalding point.

When a variation in pressure and water flow occurs frequently, the place to look in locating the source of the trouble is in the water pipes. Check the pipes to see if they are of the proper size in diameter for their length and height as originally installed. Another thing to look for is liming and corrosion inside the pipes. A large enough accumulation of liming and corrosion can reduce the diameter of the pipe and cause inadequate pressure and water flow.

The trouble sometimes occurs after additional fixtures have been installed in an existing system. When this happens, you will probably find that the piping is overloaded as a result of the additional fixtures. A variation in pressure and water flow may also occur if there is excessive friction in the pipe, owing to too many fittings and changes in direction.

If variations of pressure at showers only occur when other outlets are open. you can correct the trouble, usually, by installing automatic mixing valves. The only answer to an increase in the water flow from inadequately sized pipes is to replace them with a larger size.

VALVE MAINTENANCE

Periodic inspection of valves is necessary to maintain them in efficient operating condition. The frequency of inspection will depend on such factors as how often the valves are operated; for instance, every few minutes, once or twice a day, or only several times a year. In other words, the more frequently that valves are operated, the more frequently they should be inspected.

An important rule to follow in duties involving valve servicing and maintenance is: NEVER USE A STILLSON WRENCH ON A VALVE! Remember that the stillson wrench is designed for use on ROUND objects, such as a pipe. The ends of screwed valves are not round but HEXAGONAL in shape. The same is true of bonnet flats and packing nuts. To tighten or loosen any of these parts, USE A HEX WRENCH, MONKEY WRENCH, OR OPEN-END WRENCH. These wrenches permit a firm grip and prevent "chewing away" of the part. Tapping the handle of the wrench lightly will help unloosen a tight hex head or other screwed part. Avoid heavy, twisting pulls on the handle of the wrench.

A LEAKY valve should be repaired immediately in order to prevent waste of water and extensive damage to vital parts of the valve. A common cause of leaks in valves is the accumulation of foreign matter on the valve seat. To flush out foreign matter in the seat of a valve, open the valve part way. To prevent jamming, it is best to open the valve wide, then turn back one-fourth turn. Do not close a valve by giving the handle a quick, fast turn. Such a practice is likely to cause water to hammer on the valve.

To be on the safe side, always redisk or regrind a valve at the first sign of seepage. If you delay, the seep will develop into a leak, wire drawing of the seat will follow, and the valve will become useless. Before disassembling a valve, put the disk in open position to avoid damage.

Regrinding

All regrinding and regrind-renew valves should have a union-type bonnet. When regrinding is necessary, unscrew the union ring, remove the trimming, and place a moderate amount of grinding compound on the disk or plug. Then insert a pin in the notch of the disk nut and the hole in the spindle and re-insert the trimming.

The next, and most important, step consists of screwing down the union ring as tightly as possible BY HAND, and then backing it off about one full turn—NO MORE THAN THAT. If the valve is properly designed you can now use the spindle as your grinding tool.

To avoid overgrinding, stop as soon as the seat is renewed. Excessive regrinding will wear away the disk. By turning back the union ring only one full turn you ensure that the spindle remains truly vertical, that all parts are concentric, and that you do not cock the disk or plug. If it is cocked, the resultant seating surfaces will not be perfectly uniform or true.

When the grinding operation is complete, unscrew the union ring, remove the trimming, and thoroughly clean all grinding compound from both the disk and the seat. Then, before re-assembling the valve, remove all dirt and scale from inside the bonnet and body—especially from around joints and threads. If you will remember to oil those threads before putting the valve back together, you will find removal easier next time.

Repacking

When a leak occurs in a valve that has been in service for some time, the stuffing box most likely needs repacking. It is important to keep ample packing in the stuffing boxes, and to use the correct grade for the service. An asbestos packing, well graphited and lubricated, is best for general duty. Packing wears out due to heat and pressure, and loses its life.

Remove "lifeless" packing and repack with new material. Insert extra material soon after repacking a stuffing box to compensate for compression of packing.

SAFETY

Careful attention should be given to SAFETY if accidents are to be prevented on inside or outside plumbing jobs. As a UT 3 or 2, consider it an important function of your billet to see that safety precautions are observed at all times. Among other things, insist on the use of the right tools and the proper procedure for doing a job; require that gloves, goggles, and other special apparel be worn when necessary for protection of the worker; and keep tools in good repair and in their proper place when not in use. If you do not feel thoroughly familiar with safety practices applicable to plumbing and would like to do some studying on your own, a good place to start would be with chapter 15, section 1 ("Piping and Plumbing"), of the *U. S. Navy Safety Precautions*, OpNav 34P1. By informing yourself of the rules of safety, and then putting those rules into daily practice, you can develop that SAFETY-CONSCIOUSNESS that helps prevent accidents before they occur.

QUIZ

1. Where is the seat washer of a compression faucet located?
2. What is wrong when a new washer fails to stop a leaky faucet?
3. What is a good tool to use when a closet bowl is so clogged up that it can not be cleared with a force cup?
4. What is the best remedy for a fractured or ruptured pipe?
5. How would you make a temporary-type repair to a leaky pipe, using electrician's friction tape?
6. What is the first step in the repair procedure for a defective seam in a water tank?
7. What advantage is afforded in the removal of a closet bowl which connects to the flush tank by means of a plated elbow?
8. How is water in the trap of the closet bowl replaced?
9. What defects would you look for in trying to locate the source of trouble in the inlet valve assembly of the flush tank?
10. What is the remedy for a small leak in a copper float ball?
11. What is the remedy for a stopper ball that has lost its elasticity?
12. When using heat to thaw a frozen pipe, why should the heat be applied at one end, rather than at the middle, of the frozen section?
13. If variations of pressure at showers only occur when other outlets are open, how can you usually correct the trouble?
14. What should you do when a valve shows signs of seepage?
15. In closing a valve, why is it important to avoid giving the handle a quick, fast turn?

CHAPTER 4

SEWAGE DISPOSAL AT ADVANCED BASES

The Utilities Man's duties involving sewage removal and treatment are of major importance to the health and welfare of all personnel. As in the case of water purification, here is a service that is taken for granted; is of great significance to the welfare of the group; and must be accomplished in an effective manner.

Briefly defined, SEWAGE IS THE WASTE MATERIAL THAT FLOWS THROUGH A SANITARY SEWER SYSTEM. It consists mainly of water-borne waste matter that has been discharged by humans, and shower and kitchen wastes. It may also contain laundry wastes and other floating solids such as paper, matches, grease, and debris. The sewers, pumps, and other equipment that collect, transport, treat, and dispose of sewage make up the sewerage system.

Sewage is a liquid that usually has animal, vegetable, and mineral matter in suspension and in solution. It also contains a vast number of bacteria, most of which are harmless. However, as some of the bacteria may have been discharged by victims or carriers of infectious diseases, they are dangerous. While sewage has a number of elements in its makeup, the biggest by far is water. By weight, water is about 99.9 per cent of the total volume.

The reason sewage is collected and treated is so that it will not harm anyone, especially by spreading communicable diseases. Other reasons are: prevention of water supply contamination, prevention of damage to property; safeguarding bathing beaches, fish, livestock; and in general, preventing conditions that would be offensive to sight and smell.

At most advanced bases you will not find a permanent sewerage system established. Temporary measures are used at first. Later on, if the base is to be maintained for a large number of men, a more permanent sewerage system is set up. This chapter discusses the common temporary methods, and the next chapter covers the more permanent sewerage system plant facilities and operations. With increasing interest being shown in the Arctic, we can not overlook the problem of sewage disposal in low-temperature climates. Therefore, a brief discussion on temporary methods of sewage disposal applicable to low-temperature areas will be presented later in this chapter. Familiarize yourself with each method given, in order that you will have some idea of what your job may be like if you should have the opportunity of a temporary tour of duty in the Arctic or other low-temperature area.

LATRINES

If you are on bivouac or at a new location, the chances are heavy against your finding a water-borne sewerage system available for your use. The usual alternative is digging a hole (cat hole) about 1 foot deep and then covering the feces completely with dirt. Or you may use a latrine.

Straddle trench latrines are commonly used. These are trenches about 1 foot wide and 3 feet deep. No seats are provided and the men stand along the sides. Boards may be placed around the sides to help keep steady footing.

The earth that is dug out is piled at one end of the trench. Each man covers his excreta and paper with some of the dirt. When the latrine is filled to within 1 foot of the ground level, or is to be abandoned, it is closed. Tightly packed earth is placed over it.

If there is a possibility that others may come into the area, it is better to mark the closed latrine so that the site is not used again. A sign CLOSED LATRINE with the date of closing should be placed firmly in the earth over the spot.

As soon as possible, regular pit latrines are dug. These may go down 20 to 30 feet if the ground permits. The sides must be straight and have no ledges that could catch any feces. Latrine boxes, usually of 4 or 8 holes, and accessories such as tent, urinals, tar paper and screen wire are furnished ready for installation.

When the box is installed, it is lined with tar paper from the top to the bottom. All boxes also need a metal or tar paper urine deflector. This deflector is converted into a trough under the front of the seat so that it drains toward one end. From this end, a pipe carries the urine to an outside soakage pit. This helps prevent a disagreeable odor from the urine. In some cases where the soil is rather porous, the urine drains into the latrine pit itself.

It is necessary to cover all cracks in the box to help make it fly-proof. You do this by nailing strips of wood or tin over them. When the box is placed over the pit, it must be done carefully. If any cracks are showing, seal them by packing some dirt tightly around the edges.

A separate urine soakage pit is built if the latrine pit is in soil which absorbs liquids poorly. This pit is about 4 feet square and 4 feet deep. It is filled with pieces of broken rock, brick, or lava rock to within 1 foot from the top. Then oiled burlap is placed over the rocks and covered with sand or earth. Vents, inserted to reduce odor, are covered at the top with fine mesh screen.

Urinals may be made of 1 inch or larger sized pipe and placed at each corner of the pit and along the sides. The pipes should reach at least 8 inches below the ground surface. In the upper end of each pipe, place a funnel of sheet metal, tar paper, or similar material. These funnels are covered at the opening with wire mesh. This is to keep out flies, cigarette butts, or other items that would clog up the pipes.

In other cases, pail latrines may be found in buildings where no adequate plumbing facilities are available, or where it is not practical to build deep pit latrines. Usually a standard latrine box is adapted for use as a pail latrine as shown in figure 4–1. Hinged doors (B) enable you to remove the pail (A) without difficulty. The self-closing lids (C) help keep flies out. The pails are removed at least once daily and replaced by clean pails. Each pail should have about 1 inch of a 2 per cent cresol solution or some slaked lime in it.

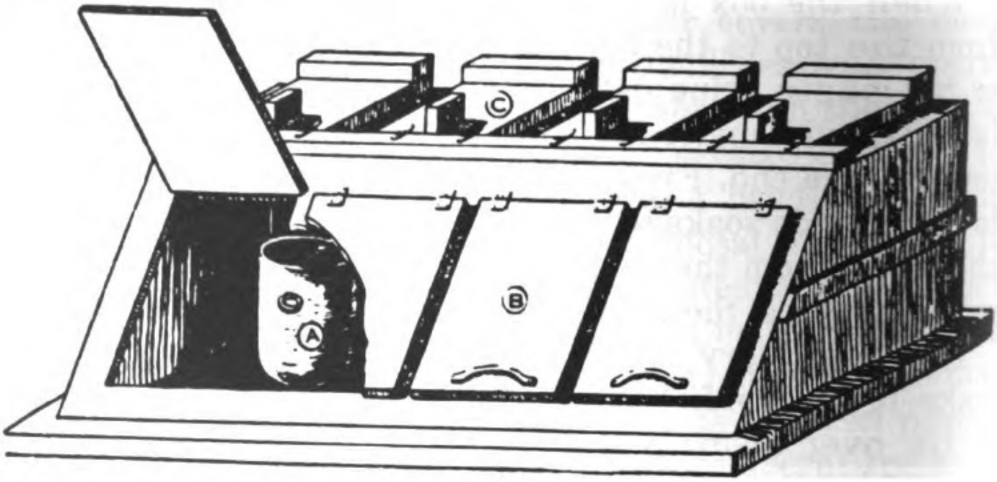


Figure 4–1.—Pail latrine.

Pails of excreta are removed from the latrines by hand, cart, wagon, or truck. The contents may be buried or placed in fly-proof concrete tanks, where it decomposes.

You will find a trough urinal built as part of a latrine. Figure 4–2 shows a common V-shaped urine trough alongside a 4-seat latrine. The trough may be made of tin, galvanized iron, or wood. If it is made of wood, it is usually lined with tar paper.

The trough slopes to one end and empties into a drain pipe. The drain pipe, fitted with a fine-mesh fly screen, extends into the latrine or wire soakage pit. Sometimes the pipe is omitted and the trough extends directly into the pit.

CARE OF LATRINES

Wherever possible, latrines and urine troughs should be protected by tents or screens. Also a ditch may be dug

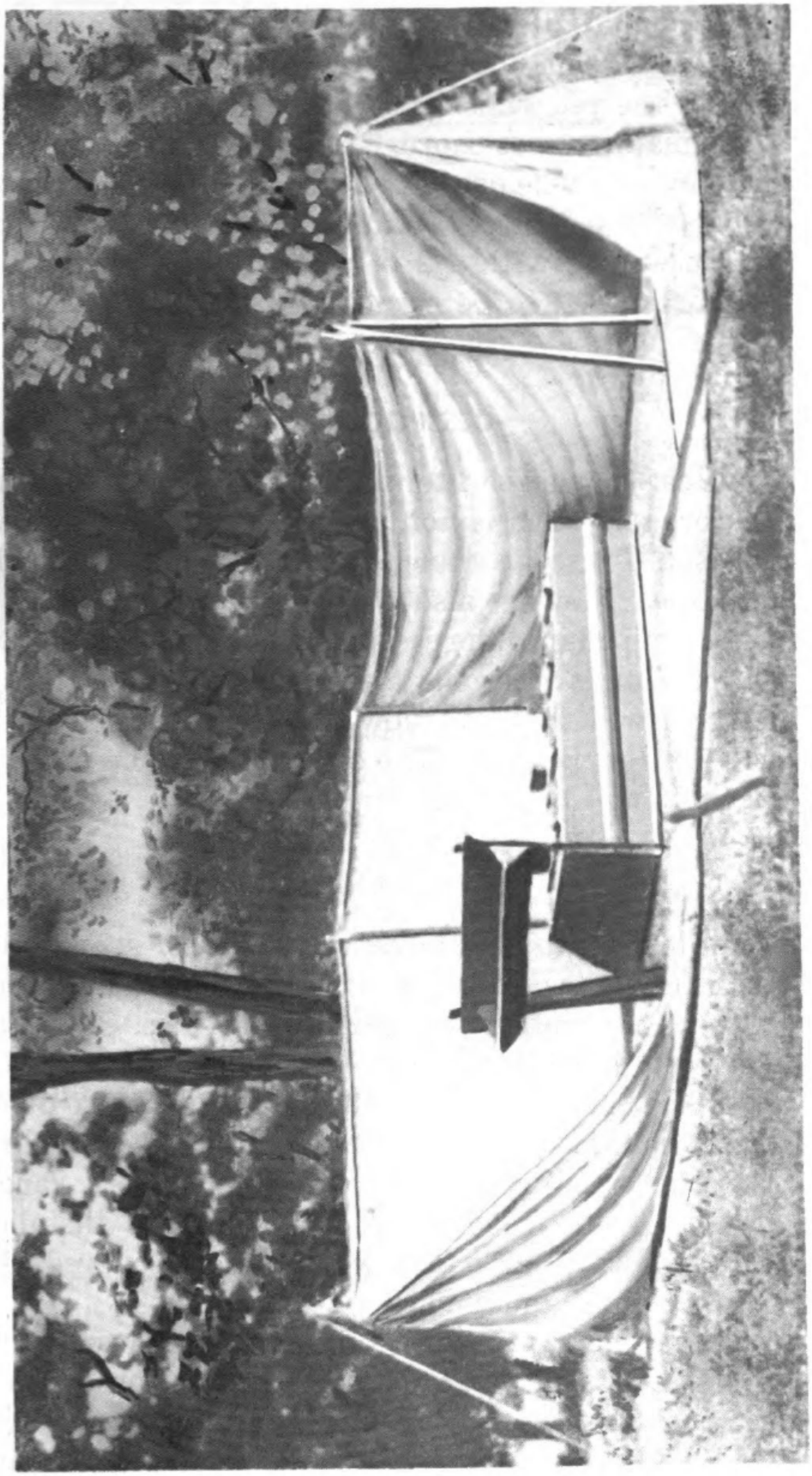


Figure 4-2.—Urine trough and latrine.

around them to drain away rain and drainage water. If flies are present, baited fly traps may be placed around to help get rid of them.

Spraying the pit walls and contents daily is the most important maintenance chore. Crude oil, DDT, or sodium-arsenite spray may be used. The outside of the box should be scrubbed daily with soap and water. Also, scrub the seats twice weekly with a 2 percent cresol solution. The urine troughs need to be scrubbed daily with soap and water.

CESSPOOLS

In some cases, where water and plumbing are available, but a sewerage system is not, cesspools are used for sewage disposal. These are holes with the sides lined with brick or stone. They are also known as "wet wells."

Sewage is piped into the cesspool where the liquid seeps into the soil. Solids accumulate and gradually clog the soil. The cesspool will then overflow and another cesspool to take the overflow is added. The cesspool must be properly covered or it will breed mosquitoes.

SEPTIC TANKS

Another method used at advanced bases for sewage disposal is the use of septic tanks. Small portable metal tanks may be used with some of the portable latrines. Chemicals are inserted to help decompose the solids. When the tank fills up, it is cleaned out—usually by a tank truck pump.

Some septic tanks for more permanent use are made of wood or concrete. Within these, the liquid depth ranges from 4 to 6 feet. Wood manhole covers are installed. Figure 4–3 shows a septic tank with the roof covered with earth except for the manholes.

The sewage enters the septic tank and usually separates itself. Some solids settle at the bottom while others float on the top. When the fluid reaches the discharge line, it goes out for disposal. At advanced bases, pits are usually

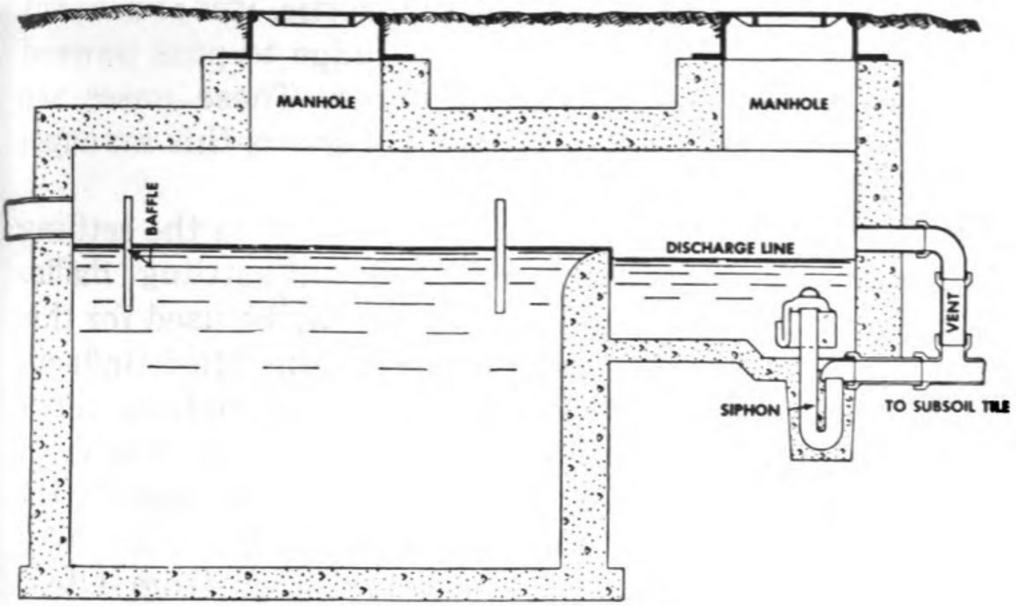


Figure 4–3.—Septic tank.

dug and the sides are reinforced by brick or stone. The effluent (materials and liquids coming out of the septic tank) goes into this "wet well."

Regular inspection and cleaning are about all that is necessary in the operation of septic tanks. Monthly inspection should be made to check the depth of the bottom and top layers. If the top layer is excessive, a considerable odor may be caused. You may add slaked lime to aid in the digestion of these solids. Two other methods of treating this condition are to spray with a hose, or to let the tank stand idle for a time. If the accumulations are too great, the tank will have to be cleaned. A truck-mounted pump and tank assembly may also be used in this case.

IMHOFF TANKS

Another tank also combines sedimentation with sludge decomposition or digestion. This is the two-story Imhoff tank named after its inventor. In this tank, however, sedimentation takes place in an upper flow chamber while the sludge is stored and digested in a lower chamber. The two chambers are connected by a narrow slot. This permits the downward passage of the solids that settle. But it does not permit the gases generated in the sludge to pass upward into the sewage in the flow chamber. These gases are vented to the atmosphere. Figure 4–4 shows this arrangement in an Imhoff tank.

The sewage must be distributed properly in the settling compartments in order to obtain efficient settling. Baffles or dividing lines of brick or concrete may be used for this purpose. Where more than one unit is installed, influent gates are adjusted to ensure equal distribution. Some Imhoff tanks have channels to reverse the flow of sewage. By reversing the flow each month, you help equalize the sludge depth throughout the sludge chamber.

The sewage is kept in the flow chamber from 1 to 3 hours. The rate of flow varies from 50 to 150 feet per hour, with the average being about 100 feet per hour.

Some of the sewage will float on the surface instead of sinking to the bottom of the compartment. This scum must be skimmed off several times daily. You can make a good skimmer by forming a basket of ¼-inch mesh galvanized screen and attaching it to the end of a long pole. In skimming, don't disturb the sewage too much or the skimmings will pass under the baffles.

A continuous spray of water helps settle the floating solids. After you remove the skimmings, you may bury them or burn them in an incinerator.

All walks, wall tops, and inside walls must be washed down at least once each day. If solids are sticking to the sloping bottom of the upper compartment, use a long-handled squeegee once a week or more often and push them into the slots. At the same time, clean the slots. One way of doing this is to drag a 3-foot, heavy chain, mounted on a pole, along the slot. You have to be very careful in these cleaning operations to avoid excessive stirring which may disturb the normal settling process.

The sludge compartments are normally kept quite full of sludge, but not above a level 2 feet below the slots. When the plant is operating near capacity, you need to

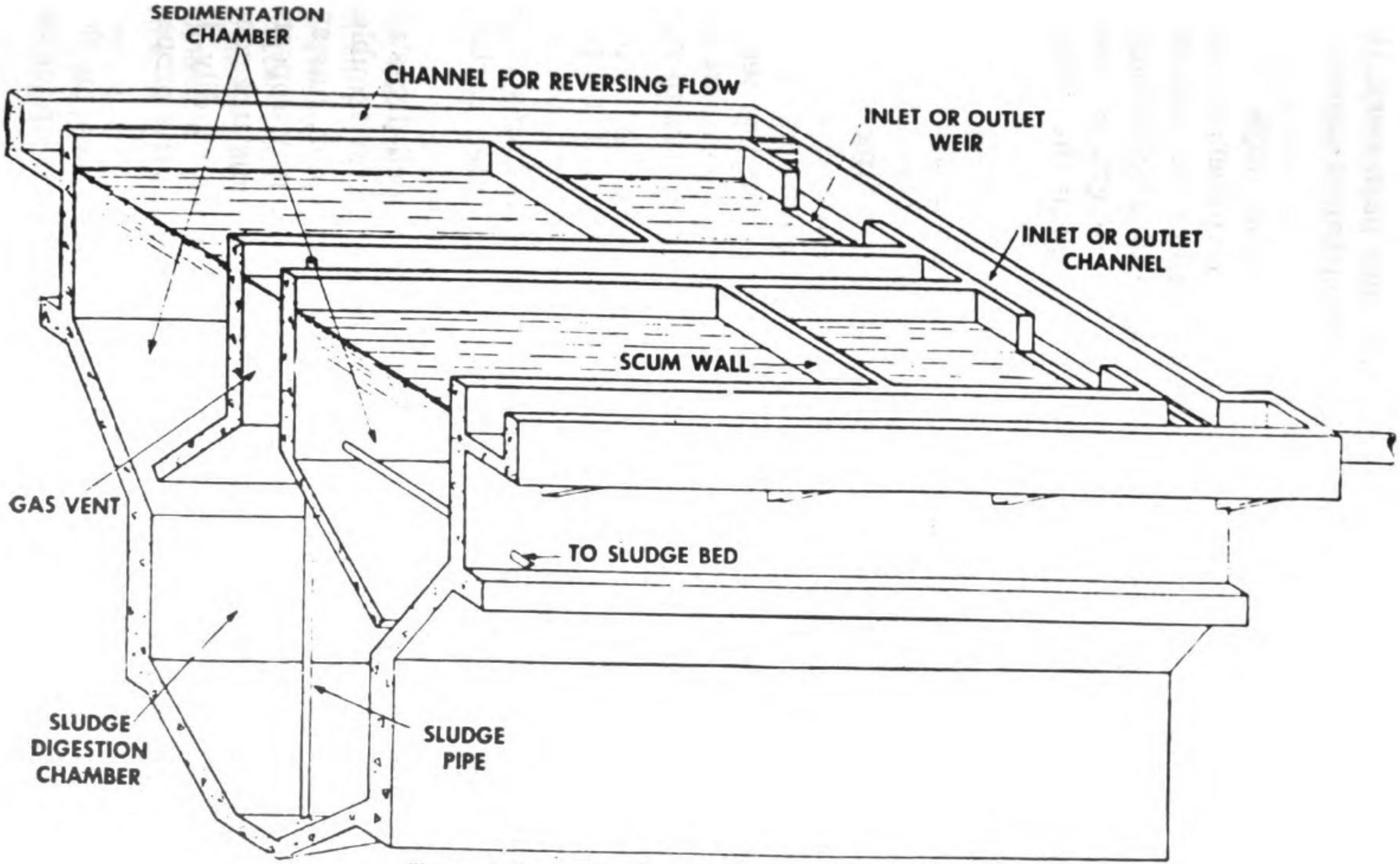


Figure 4–4.—Sectional view of an Imhoff tank.

check the depth of sludge in the sludge compartment at the inlet and outlet ends of the tank once each week. If less than 75 per cent of the sludge-compartment capacity is in use, monthly tests are adequate.

You may measure the depths in several ways. One method is to equip a pitcher pump with a rubber suction hose, weighted on the end, with markings on the hose at 2-foot intervals. You lower the hose gradually through the slot while operating the pump. The length of hose immersed when the sludge first appears, equals the sludge depth.

When a new or a clean tank is placed in service, it will take some time before the bacterial activity in the sludge is sufficient to produce thorough digestion. This may take from 2 weeks to 2 months or longer, depending on the temperature and the character of the sewage. A shorter time is required in warm weather than in cold. The ripening of the sludge in a clean tank may be hastened by seeding it with digested sludge from a tank in operation or by letting in some fresh water through water lines to the sludge chamber.

The sludge must have an alkaline reaction if proper digestion is to be obtained. If an acid decomposition occurs, it will produce a light-colored, foul smelling sludge which will be difficult to dry. Lime or activated carbon is used in maintaining the proper *p*H reaction.

The Imhoff tank is intended to produce a well-digested sludge which can be disposed of with minimum trouble. Ripe Imhoff tank sludge is a black or dark color, has an inoffensive tar-like odor, and a granular or frothy appearance. It has a *p*H normally above 7.0 and a moisture content of about 90 per cent. It drains and dries readily. It is important, therefore, to remove the sludge at the proper time and in the proper amounts.

You remove the sludge by opening the valve on the sludge pipe. The sludge flows through the pipe under its own pressure, or it may be pumped.

When you are sure that the sludge is ripe, you remove it in small amounts at frequent intervals. This may be every 2 to 6 weeks if the disposal facilities permit. Only well-digested sludge is drawn, with enough left to provide proper seeding to prevent acid digestion. Usually not more than one-half the depth of sludge in the tank may be removed at any one time. Long rainy seasons, snow on the ground, and availability of drying beds may affect the withdrawal rate. In northern climates, for example, the sludge level must be lowered during the summer and autumn to make room for the winter accumulation. During the winter months, when it is difficult to dry the sludge, you may find it necessary to allow it to accumulate in the tank. However, if the sludge gets to within 18 inches of the slot it should be removed. When less than 18 inches of free space is below the slot, the currents resulting from the production of gas in the sludge may carry decomposing solids through the slot into the outgoing effluent.

The digested sludge must be drawn slowly to keep from forming a cone within the sludge and removing some of the partially digested sludge and sewage. If the sludge clogs the withdrawal pipe, you may start the flow again by agitating the sludge with long rods through the slots, gas vents, or the sludge riser pipe. Opening and closing the sludge valve also may relieve the clogging. Or you may lower a hose in the sludge riser pipe and let in some water under pressure. After the sludge is drawn, clean the lines with water so that solids will not dry and harden in them.

The surface of the gas vents must be broken up and wetted once each week or oftener if necessary. This is done to allow the escape of the gas and to help the scum digestion. You may do this by using a rake or hoe, or by spraying the scum with water under pressure. If the scum freezes over, check it so the gas vents don't block the escape of the gas. Some tanks collect and store the gas generated in the sludge. They use it for heating or power purposes and as an odor control method.

One of the major difficulties with the operation of the

Imhoff tank is the prevention or treatment of a condition called foaming. You have foaming when you see black suds or foam in the gas vents. You'll also smell a very disagreeable odor. This has come from the gas in the sludge which may be strong enough to force relatively large quantities of solid material up into the gas vents. Foaming may also interfere with the digestion and removal of the sludge. If it is not checked, the foam will overflow into the flow chambers.

It is difficult to prevent foaming. Seeding a new or cleared tank with well-digested sludge from another tank or with well-rotted horse manure is helpful. Prechlorination and adding hydrated lime are two other methods used.

Several alternatives are available to control the foaming if, after careful operation, it has occurred. Spraying with a garden hose or pumping some of the digested sludge from the bottom into the gas vents are methods used. You may, however, put the tank out of service until the foaming subsides, or remove the digested sludge during the foaming period if the sludge compartments are heavily loaded. If the drawing method is used, applying some hydrated lime during the operation will help reduce any offensive odor and fly breeding.

GARBAGE DISPOSAL

Garbage is the waste from the kitchen and mess hall. It is usually divided into two categories—WET and DRY. Both have to be removed from the mess area before they cause offensive odors or attract flies and rats.

Cans are used for storing the garbage until it is removed for disposal. They are kept outside of the kitchen. Covers must be kept on the cans at all times. Cans should not be filled higher than 4 inches from the top. Regular washing of the cans is necessary to sanitation. If steam is available, it may be used to remove any accumulated grease.

The common method of disposal is burial. Trenches or pits are dug and the garbage deposited. Sometimes a continuous trench is used. Each day's garbage is then covered by the excavation made for the following day. The length, width, and depth of the holes vary according to the need. However, do not pile the garbage higher than 2 feet from the top before covering it with earth.

Some installations may have facilities to load the garbage on barges. The barges are taken out to sea and the garbage dumped. Where available, movable platforms accomplish this without the need of handling the garbage again.

At a few installations "garbage dumps" may be found. Here dry garbage is burned. This method may be used where possible as it is an inexpensive and quick way of disposal.

LOW-TEMPERATURE CLIMATES

In low-temperature areas, such as the Arctic, the problem of sewage and garbage disposal is more difficult than in temperate or normal temperature areas. The difficulty is due, in particular, to the effect of the low temperature on the physical state of fluids, soils, and other materials involved in garbage and sewage disposal.

The biological and chemical reduction of organic material is a slow process under low temperatures. The soil will not assimilate wastes as readily as under normal conditions, and permafrost (or permanently frozen ground) often will not permit proper drainage of the soil. In addition, most solids, as well as liquids, will show a decline in solubility with a decline in temperature. These and other such factors have an important bearing on the type of sewage and garbage disposal methods used in the Arctic or other low-temperature areas. Let us consider briefly a few temporary methods suitable for use in such areas.

Excreta Disposal

In severely cold weather, feces deposited by troops will freeze quickly, and when pulverized by wind and snow can soon contaminate a whole area. Sometimes, on a march, a SNOW HOLE may be used, but it should be placed near a rock or terrain feature that will ensure against other troops placing a tent on the same spot at a later date.

DISPOSAL BAGS offer a good means of preventing the spread of contaminated material and should be used whenever possible. These bags are collected and stacked under rock cairns, then disposed of later by dumping on the ice of adjacent bodies of water. The bags present no problem while frozen, and they can not be scattered until the thaw begins.

In forward bivouacs, about the most elaborate set-up you can expect is a SLIT TRENCH in the snow, protected by a windbreak. It should be located in close proximity to the group and marked. This will prevent placing a tent on the spot—unless snow drifts over the area and reaches a depth that makes this unimportant.

In a more permanent type camp, a heated shelter probably will be provided. This may be a tent or prefabricated unit in which there is a portable folding box latrine.

Portable Equipment

You can readily understand why use of the old-fashioned privy would be undesirable in the Arctic, when you stop to consider the great inconvenience and discomfort that would be encountered on a bitter cold night. Installation of this facility would pose a further disadvantage because of the difficulty involved in digging through permafrost, or permanently frozen ground.

In a region as cold as the Arctic, providing toilet facilities in the buildings where men live and work is more than a convenience—it is a necessity! One way of doing this is to provide each hut with a SLOP JAR. It is important that this container be emptied and cleaned daily. A community dump should also be provided for final disposition.

Another method involves the installation of a combined septic-Imhoff tank in the building, with the effluent treated to be free of bacteria. A typical septic-Imhoff tank uses a minimum of water, averaging about 3 quarts per flushing. The sewage passes from the water closet through a 3-inch stainless steel pipe located beneath the floor, where it enters a digester below the liquid level. The floor serves as the top of the digester which, basically, is a two-compartment septic tank. Liquefication of the sewage by the digester is through bacterial action.

Sludge which forms in the unit can be removed by means of a vacuum pump. After removal, it should be taken to some remote spot from the camp, dumped, sprayed with gasoline and burned. This method of incineration should destroy much of the bacteria that may be present in the sludge.

If assigned to an activity having the septic-Imhoff tank as part of its sewage system, always familiarize yourself with the manufacturer's instructions before attempting to make any operating or service adjustments to the unit.

Garbage Disposal

During the summer, in most subarctic areas, conditions probably will permit the use of a SANITARY FILL for the disposal of garbage. The fill is dug by earth-moving equipment. It is important that you make a special effort to keep the fill covered with earth. This precaution is essential to the prevention of flies and rodents.

In winter, edible garbage can be disposed of in low areas located a safe distance from the camp, where it can be consumed by wild animals. Tin cans and other nonedible trash can be crushed and then placed on the ice of adjacent ponds, rivers, and streams. When garbage is to be dumped on river ice, make sure it is placed away from the shore so it will be carried away during the spring thaw. Always exercise care to avoid contamination of any nearby water supply source. Signs should be used to mark all garbage or dumps so as to warn persons who may occupy the area at a later date.

SUGGESTED REFERENCES

Because of the vital effect of garbage and sewage disposal on the health and welfare of naval personnel, it is to your advantage to learn everything possible about this important subject. Considerable information is contained in this chapter and the one which follows; however, the subject is much too broad to permit complete coverage in this text. If you can spare some time for additional study on your own, a suggested publication which should prove helpful is *Refuse Disposal,* TP–Pu–1. In it you will find detailed information that will serve as a guide in organizing an efficient collection, segregation, and disposal system at a naval establishment.

An excellent reference on garbage and sewage disposal in low-temperature areas is *Low Temperature Sanitation,* by the Technical Assistant to the Chief of Naval Operations for Polar Projects (June 1954). Topics discussed in this suggested reference include individual waste-disposal systems and sewage treatment in low-temperature areas, as well as garbage collection, sanitary fills, and other methods of garbage disposal.

QUIZ

1. Why may sewage be dangerous to health?
2. Of what material is the greater part of sewage composed?
3. If soil conditions permit, to what depth are pit latrines dug?
4. How is the pit of a latrine kept sanitary?
5. How often should urine troughs be scrubbed?
6. What happens to the liquids piped into cesspools?
7. How often should septic tanks be inspected?
8. How can you help equalize the sludge depth throughout the sludge chamber of an Imhoff tank?
9. What is the maximum height desired in the storing of sludge in the Imhoff sludge chamber?
10. How can you hasten the ripening of sludge in a clean Imhoff tank?
11. What is the common method of garbage disposal in temperate climate areas?
12. When a snow hole is used on the march, in low-temperature areas, why should it be placed near a rock or terrain feature?
13. In low-temperature areas, what happens to disposal bags after they have been collected and stacked under rock cairns?
14. What is permafrost?
15. What should be done (in a low-temperature area) with the sludge removed from a septic-Imhoff tank?
16. What method can be used to dispose of tin cans and other nonedible trash in low-temperature areas?

CHAPTER 5

ROUTINE DUTIES IN A SEWAGE DISPOSAL PLANT

At larger and more permanent installations, you may find a sewage collection system. This has a network of sewers and pumps which collect and transport the wastes to a sewage treatment plant. These sewers are cleaned regularly so that the sewage will go through without overflowing or clogging.

At the treatment plant, the liquid and the solids receive several different processings. The equipment and treatment may vary according to local needs. Figure 5–1 will give you an idea of what the sewage disposal plant may look like at some activities.

One of the treatment processes, known as PRIMARY TREATMENT, is used to remove part of the suspended and floating solids. This is done by passing the sewage through screens or grinders. Because the fine suspended solids are not completely removed, further screening by fine screens may be next. Or the sewage may go to sedimentation tanks. Here the solids settle to the bottom of the tank. Septic tanks are also used for the settling of solids. In them, the settled solids decompose. In some plants, Imhoff tanks may be used as a method of removing and treating the suspended solids. In these two-story tanks, settling takes place in the top compartment and decomposition in the bottom compartment.

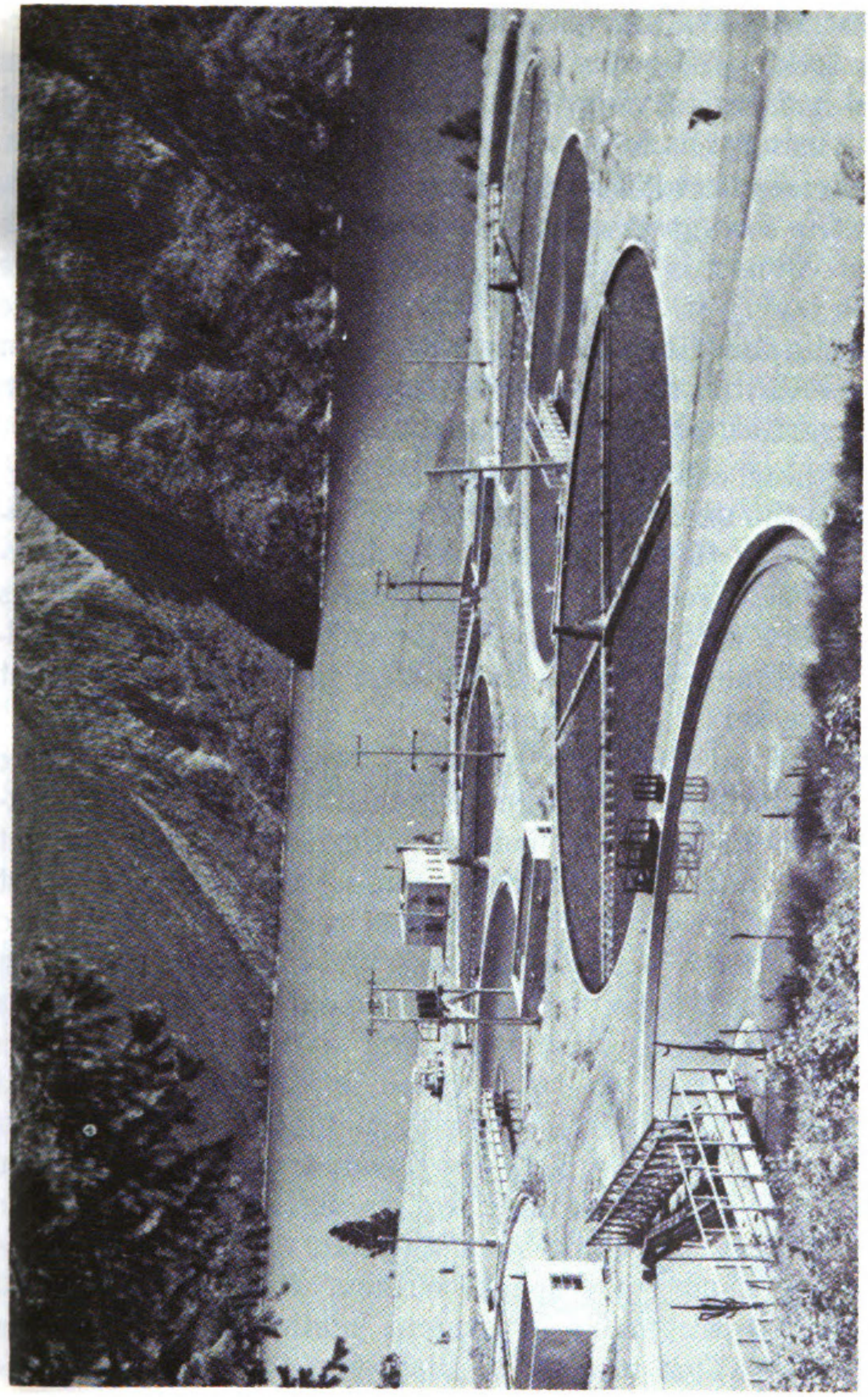


Figure 5–1.—Sewage disposal plant.

The solids, known as sludge, that have settled to the bottom of the sedimentation tank are placed in separate digestion tanks. Here the sewage is reduced to inert odorless solids. After the sludge is digested, it is placed on sand beds for drying. The dried sludge may be disposed of by using it as fertilizer or as a filler for low ground.

In many localities, this is all the treatment given before the sewage goes out for disposal. In these cases, the plant effluent is sent into a body of water where nature helps purify it. The primary treatment has made it safe enough, and dilution takes care of the rest. However, in some localities it is desirable or necessary to do more than this partial, primary treatment.

In these cases, the sewage is given more processing. This is the SECONDARY TREATMENT which aims at removing more of the finely suspended matter and also at making the sewage liquid less objectionable. Using oxygen as a mixture with the sewage is the chief feature of secondary treatment. It makes the sewage safer for disposal but not necessarily 100% pure.

One of the secondary processes consists of passing the sludge and liquid through beds of stone known as trickling filters. Other methods of oxidizing include contact aeration and the activated sludge process. The first method mixes oxygen and sludge by having compressed air come from perforated pipes under contact plates in the tanks. The second method mixes sewage that has already received primary settling with sludge that has started to decompose and which is known as activated sludge. This mixture results in a mixed liquor that is treated with compressed air through diffuser plates or is sprayed by mechanical aerators. After this, the liquor may go to a secondary settling tank for more clarification and then for disposal without further treatment. The third secondary treatment method is subsurface irrigation. This method of disposing of septic tank effluents uses subsurface tile fields.

At plants, you will also find laboratories that analyze samples of sewage and perform various tests. Tests are made for alkalinity, total and dissolved solids, grease, nitrogen compounds, carbon dioxide in the digester gas, moisture in the dried sludge, and other analytical purposes. You may find chlorination used in the same general manner as at a water treatment plant. It is used for disinfection of the plant effluents, odor control, and to facilitate the various treatment processes.

GRIT REMOVAL

One of the common processes found in most plants is grit removal. This process is just what it is called. The sewage reaches a large channel or long tank called the GRIT CHAMBER at the influent (incoming) end of the plant (fig. 5–2). This chamber slows down the flow so that the heavier solids settle to the bottom. Such items as sand, gravel, and coffee grounds are stopped here. This process of removing such coarse matter helps avoid excessive wear and clogging of the plant's pumps and other equipment.

The grit, except for the very fine stuff, will settle quickly when the flow of the water is reduced to about 1

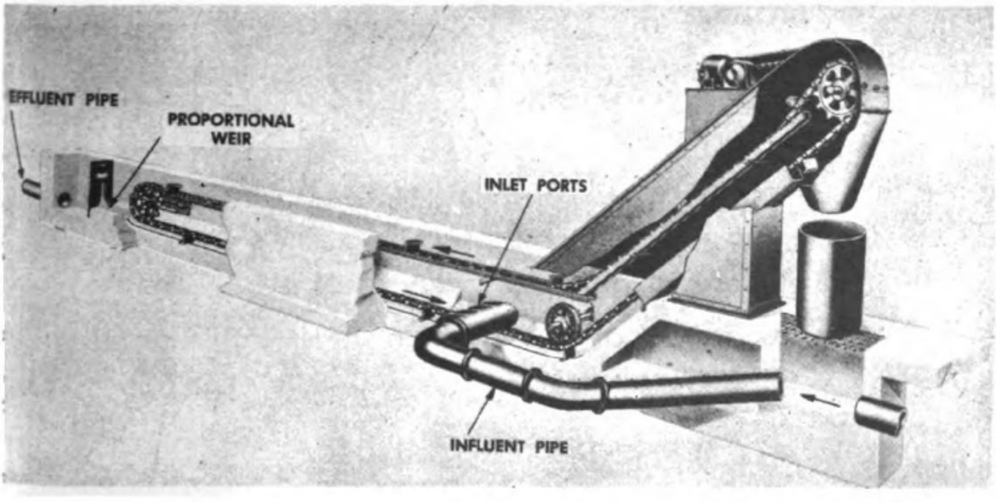


Figure 5–2.—Grit chamber.

foot per second. Regulating devices, such as proportional weirs, shown in figure 5–2, maintain the desired rate. If no automatic device is available, stop gates are used.

If the flow gets too slow, material which still contains living organisms will also settle with the grit. This will decompose and produce bad odors. If more than 15 per cent of the settled grit is organic material, there is need for a change in operating the chamber or perhaps for a new chamber of different design.

The grit depth may be measured by a pole with a small board attached to the end. When you find that 50 to 60 per cent of the chamber is filled, it is time to remove the grit. Close the end gate and drain or pump the water out of the chamber. As the water drains out, stir and scrape the material away from the drain. This will help remove the organic material. If the grit still has some organic matter, flush it carefully. When the grit chamber is drained, remove the grit with shovels or buckets.

At large plants, mechanical grit removal equipment is operated. A conveyor-type grit removal mechanism is shown in figure 5–2. The conveyor picks up the grit at the foot of an incline and removes it. Each manufacturer has instructions for the operation, lubrication, and maintenance of his machine. These must be followed as closely as possible.

During the operation of the mechanical grit removal equipment, the organic material is washed out. However, it may be necessary to flush the walls of the chamber channels frequently to remove grease accumulations. Another maintenance requirement is to keep all metal parts above the water line well painted.

The grit collected is usually used as fill. If odors due to organic matter are present, it may be necessary to bury the grit.

SCREENS AND GRINDERS

It is wise to separate as many solids as possible in as easy a way as possible. To do this, some plants have screens, either coarse or fine or both, or they may have comminutors or grinders (fig. 5–3). These eliminate large objects such as rags and wood, which may clog the pumps and other equipment. In some cases, fine screens with ¼-inch openings or less may be used to remove other of the suspended solids.

The coarse screens are known as bar screens. They consist of a rack of steel bars ¼ to 2½ inches apart. The bars are at an angle of 30 to 50 degrees in the direction of the flow. They are extended across the channel so that all of the sewage must pass through the screen.

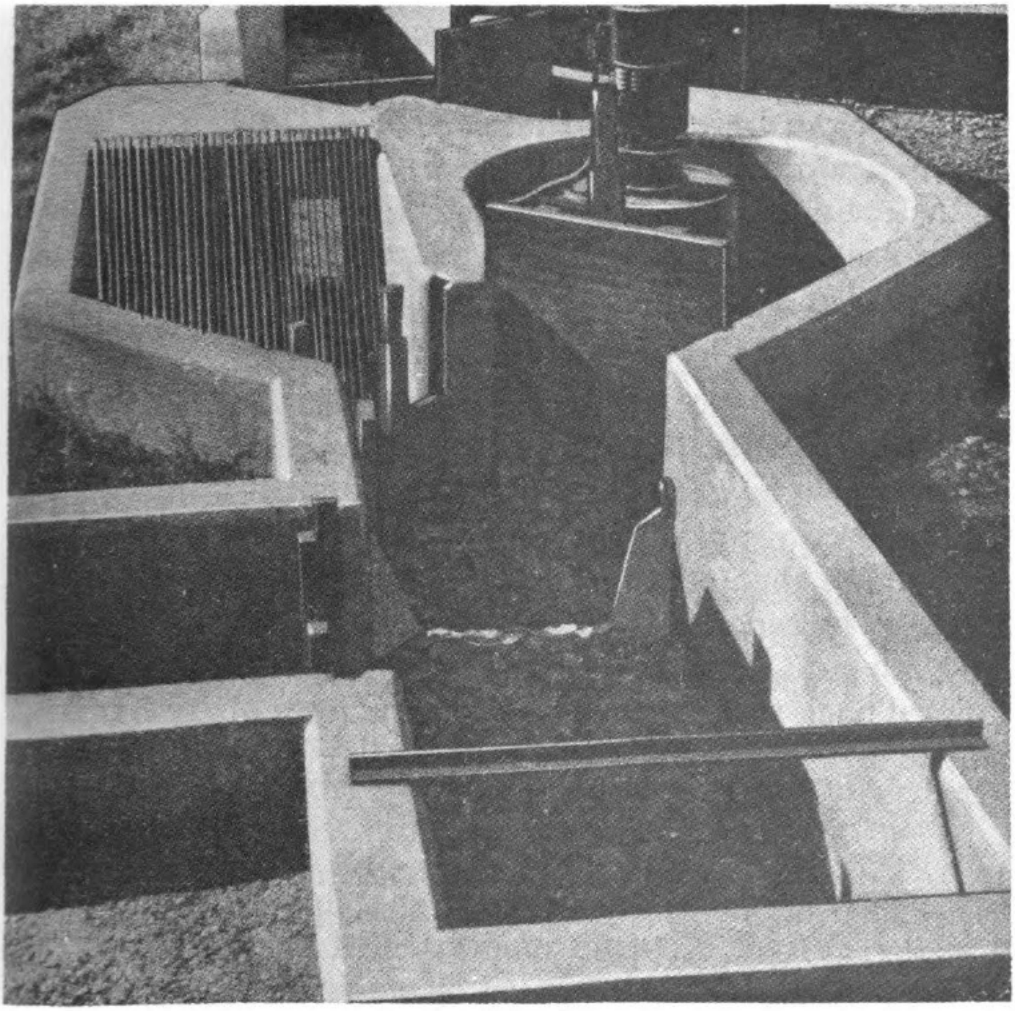


Figure 5–3.—Bar screen and comminutor.

You clean these screens by raking them upward. The teeth of the rake should fit between the bars of the screen. The solids that have been removed are placed in a wheelbarrow or on a draining platform. They are disposed of by grinding, burying, or using them as fill. You should clean the bar screens and the inlet channel by flushing it with a hose at least once a day.

In larger plants, you may find that the bar screens are cleaned by mechanically driven rakes or other devices. These may be operated by a time clock or a float switch that will set the cleaners going when the screenings accumulate on the bars. The screenings are raked upward and dropped into a receptacle or a grinder.

Fine screening is used in some cases where all the coarser substances and a part of the finer suspended solids are to be removed. One type of fine screen is a rotary drum that permits the sewage to enter at one end of the cylinder. The cylinder rotates and the water flows out through the openings in the screen which makes up the walls of the cylinder. The solids are collected inside the drum and are removed by conveyor devices of different kinds.

At some plants, the sewage goes past a comminutor in the inlet channel. This has a set of cutting knives revolving on a vertical drum. As solids that are too large to go through the openings between the knives come along, they are forced against the knives again and again until they are cut to the proper size. The shredded material is washed back into the raw sewage and goes on for further treatment.

Daily lubrication is needed for the lower shaft bearings, and weekly lubrication for the other moving parts. A daily washing of the comminutor chamber to remove grit is also required. Monthly inspection of the cutting teeth is advisable as worn teeth must be sharpened immediately or they will become so flat that they will have to be replaced.

SEDIMENTATION TANK

A sedimentation process is used at sewage plants to separate the solids from the liquid. Sewage is admitted into tanks so that some of the solids will settle to the bottom and be removed. These tanks may be circular, square, or rectangular, and shallow or deep. This sedimentation process is similar to the sedimentation process in water purification treatment.

The inlets of the tanks reduce the velocity as quickly as practicable. Baffles (deflectors) are helpful in this. They also help to distribute the sewage throughout the tank. A baffle is also placed behind the outlet to check the escape of solids in the outgoing fluids.

The flow of sewage as it passes through the tank is reduced to 30–75 feet per hour. This enables solids to settle and also keeps the deposited material or sludge from being lifted up and carried out of the tank by currents.

The average length of time the sewage remains in the tank is from 2 to 3 hours. The detention period may be lengthened if a finer degree of sedimentation is required. Usually, plain sedimentation will remove from 50 to 60 per cent of the suspended solids.

The sludge must be removed before it starts to decompose. Today's plants are using mechanical devices to collect and withdraw the sludge from the sedimentation tank. These are designed to fit the tank. Figure 5–4 illustrates one type of sludge collector mechanism.

Operating conditions determine the number of times the sludge is removed. It may be removed continuously during the day or from one to several times a day.

Some of the tanks have automatic devices that skim off the scum on top of the sewage. If this epuipment is not available, you may use a wire mesh tool.

Proper sludge withdrawal is important to settling efficiency. The sludge's solids content should be as high as

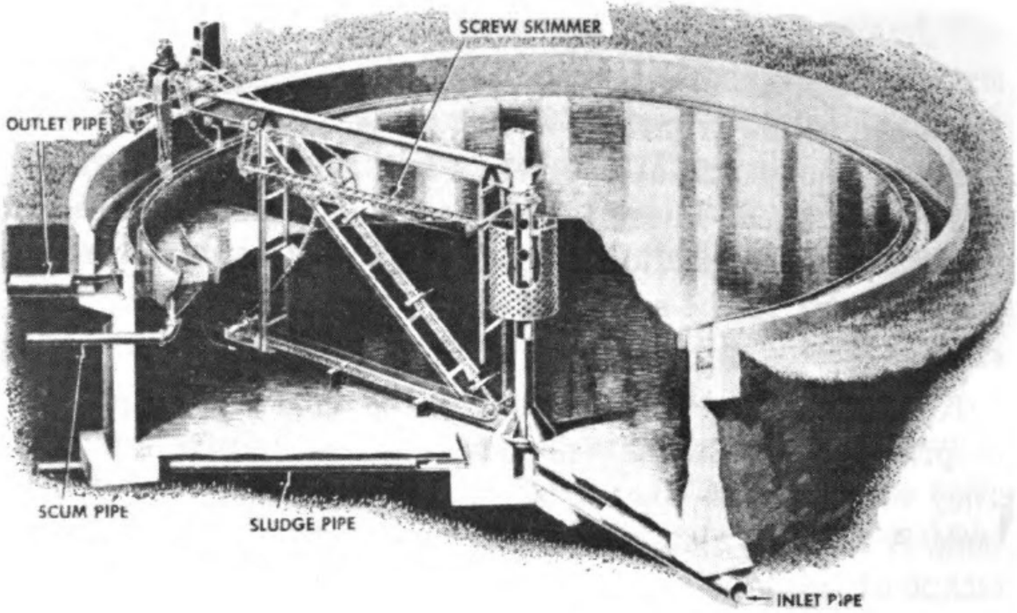


Figure 5–4.—Circular primary settling tank.

possible. This means that you'll stop the withdrawal when the sludge becomes thin. Normally, a slow rate of withdrawal is common.

The mechanical sludge collectors in circular and square tanks are operated continuously. This keeps the solids from accumulating on the tank floor and from placing a heavy starting load on the collector. In rectangular tanks, the collector need not be operated continuously. It may be done if the sewage is strong and the rate of flow high. If you discover rising gas bubbles and sludge along the tank, it means that there has been incomplete cleaning or too long a period between operation of the collectors.

If sludge-collecting devices are not available, a hopper bottom tank is used. The sludge accumulates in the hoppers and is removed by withdrawal pipes. The hoppers in rectangular tanks should not be filled more than 6 inches from the top. In withdrawing sludge, 2 feet of sludge blanket may be left in the hopper. If the tanks have 2 or more hoppers, empty one at a time.

Good housekeeping practices are needed to prevent odors, flies, and unsightly appearance. Clean the sidewalls of the channels, the baffles, and tanks with a hose, or by scraping or brushing. This should be done once each day; more often, if necessary. Dead ends and corners need brushing at least once each watch. All decks and walks need washing at least once each day. The hoppers have to be squeegeed several times each week to remove any solids sticking to the sides.

SEPTIC TANKS

Another primary method uses septic tanks to settle solids and also to decompose them. The septic tank discussed in chapter 4 may also be found at plants for sedimentation, storage, and decomposition. Ordinarily, they are about 6 to 18 feet in depth and are rectangular concrete basins. The tanks are relatively small so that the septic decomposing process may be more easily controlled.

Odor control is a problem, as gases generated in the decomposing organic material may be objectionable even at a distance of a mile or more from the plant. Cleanliness is the chief answer. All decomposed solids should be properly disposed of. All exposed parts of the tanks and channels should be kept free of decomposing matter. Prechlorination also is an effective aid in reducing odors.

SLUDGE DIGESTION TANKS

It is not always desirable to have a two-in-one like the Imhoff tank. In recent years, separate sludge-digestion apparatus and procedures have been developed. Instead of the sludge chamber being connected to the settling chamber, it is completely apart from the settling unit. This method of treating the sewage is found to be quite practical and efficient.

The digestion tank, or tanks, may be located nearby or at a distance from the settling tanks. The basic feature of this digestion method is the transfer of fresh sludge to a separate tank where it is retained until it decomposes. The sludge may be completely digested in one tank. Or, it may be partially digested in a primary tank, and then transferred to a secondary tank. In some plants, the primary tank is heated by hot water coils within the tank, and the secondary is not heated. If both are used, the primary tank is smaller than the other.

There is a great variety in shape and design. The tanks may be circular, rectangular, or square, and range from 10 to 40 feet in depth. The bottom of the tank is designed to fit the method of removal of the digested sludge. If mechanical equipment is to be used, the tank is commonly circular in shape and has a comparatively flat bottom. If the sludge is removed by gravity, the bottom is hopper shaped. Some digesters also have mechanical stirrers. Usually, the roof is fixed and domed to provide space for the gas to collect. Some tanks have floating covers which lie on top of the contents of the tank. Figure 5–5 shows a digester with a floating cover.

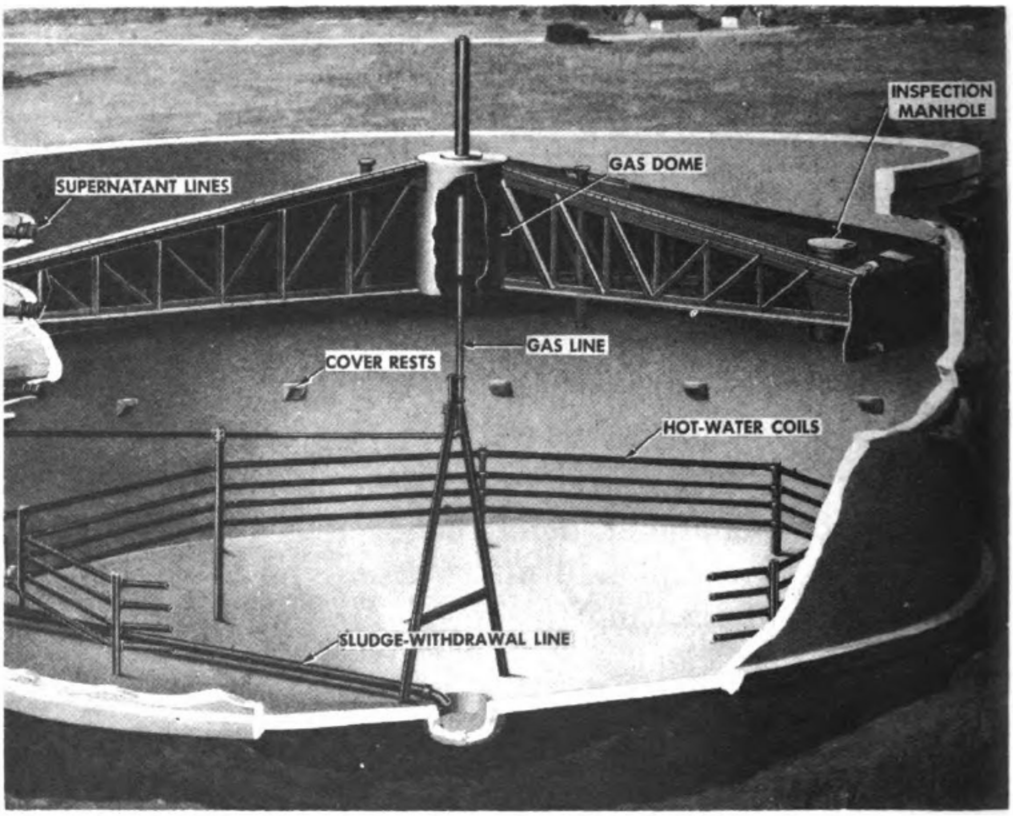


Figure 5–5.—Digester with floating cover.

Before tanks are put in service, they should be carefully inspected, all debris removed, valves and stirring mechanism checked for proper operation, pressure-vacuum relief valves on covers adjusted, and all piping made tight and cleared of obstructions. You also must eliminate all air accumulated below the fixed-cover digesters. You'll be able to do this by filling them completely with raw sewage or water. If you are operating a floating cover tank, open the hand hole in the gas dome. Then fill the tank enough to lift the cover from its low-level supports.

In starting a digester, you should seed it with partially or well-digested sludge whenever possible. This may come from septic tanks, Imhoff tanks, or other digesters.

In heated tanks, the contents should be brought to between 95° and 100° F. Auxiliary fuels are used until enough digester gas is available to heat the contents. If you are starting an unheated tank during winter, you may add lime to the raw sludge to help start digestion. The heating helps promote rapid decomposition and more thorough digestion at a uniform rate.

Fresh raw sludge is added to the digesters as frequently as possible. If more than one tank is available, the flow may be rotated. Too much sludge in one tank may induce foaming, reduce the *p*H value, and retard the digestion.

Pumps may be operated to stir and circulate the sludge. They may be operated 2 hours daily. For one hour, the circulation should be from bottom to top, and the rest of the time the flow should be reversed. The rotary-stirring devices may be operated at all times in order to keep the digested sludge from accumulating in remote parts of the tank. Stirring is useful as it hastens digestion, thickens the sludge, decreases its moisture content, and breaks up the scum.

Well digested sludge is similar in character to that produced by an Imhoff tank. It is usually removed from the tank by gravity. You should never let the sludge be higher than 18 inches below the overflow mark nor should all of the ripe sludge be withdrawn. At least 4 feet of sludge should be left for seed purposes.

As the digestion goes on, sludge liquor and gases are produced. The liquid is removed and passed through sand filters, or discharged in small quantities into the sedimentation tank or into the incoming sewage. The gas may be used to heat the sludge or to burn as waste.

In maintaining the digesters, you'll have to inspect all automatic control devices and all of the machinery frequently. The machinery should be well lubricated and protected according to the manufacturer's instructions. All the surroundings should also be kept clean and shipshape.

There is danger in operating a digester if care is not exercised. "No Smoking" signs should be posted near the digester. And you should see that ALL lighted cigarettes, and the like, are kept away from the digester at all times. Also keep the tank filled at all times. Never enter a digester that has been emptied unless it has been purged with live steam or carbon dioxide.

SLUDGE DRYING AND DISPOSAL

It is necessary to get rid of the sludge also. Well-digested sludge from the separate sludge digester or the Imhoff tank has a water content of 90 to 96 per cent. It is generally dewatered by being placed on underdrained sand beds or on a natural sand area. The sludge drying takes place both by evaporation from the surface and drainage through the sand and gravel.

The common sludge bed has a level sand area 6 to 12 inches deep supported by 6 to 8 inches of graded gravel. Below the gravel are open joint tile underdrains laid on the ground and leading into a main drain. The floor of the bed is natural earth with the walls of wood, concrete, or earth. A treatment plant will have a number of these drying beds, with their sizes depending upon the plant size and the average drying time. (See fig. 5–6.)

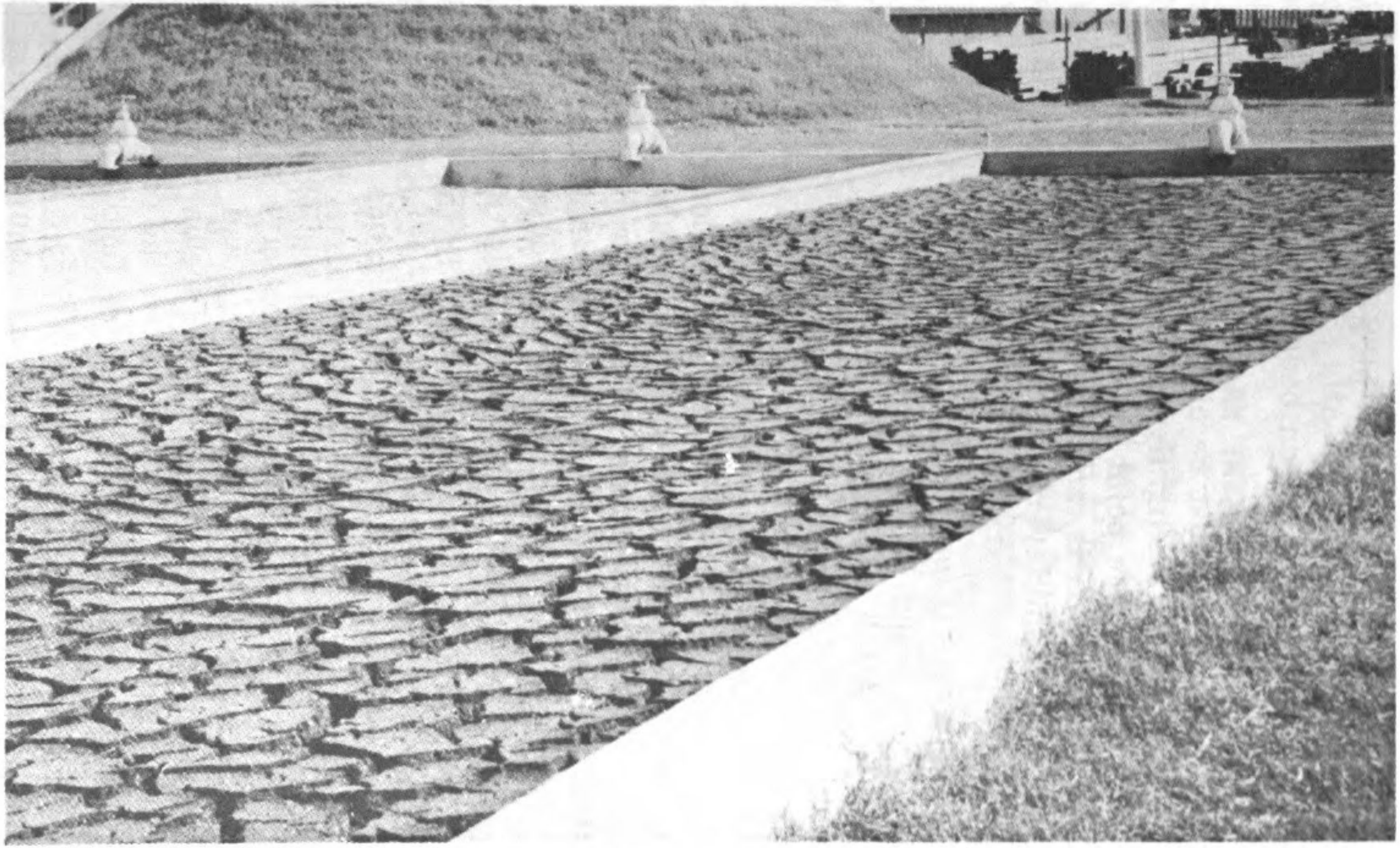


Figure 5-6.—Sludge drying beds.

As most of the drying beds are uncovered, the weather conditions will affect the drying periods. In summer or dry seasons when digestion and drying proceed rapidly, the beds are recharged frequently. During cold or wet weather, drying on the open beds is retarded and other means may be necessary.

The sludge beds must be clean before you use them. Rake the sand surface lightly and level it off with a slight slope away from the point where the wet sludge enters. Sludge chunks, weeds, and other debris need to be removed. If the sand layer gets below 4 inches, you'll have to add some clean coarse sand.

Sludge comes through pipes or channels to a concrete apron from which it flows over the drying bed. It is spread to a depth of from 8 to 12 inches. If an excessive amount of sludge is applied, the drying period will be much longer than normal. Where there is ample bed area, it is best to apply sludge to the maximum depth for best drying. Allow it to remain on the beds as long as possible. This will reduce the moisture content and a minimum amount of dry sludge cake will have to be handled. It will take from 10 days to 6 weeks or longer for drying.

If there is limited drying space, you may use chemical coagulants to speed the drying process. Alum solution, mixed with the sludge as it goes to the drying bed, is most effective. In case undigested sludge has to be put on the drying beds, add some chloride of lime to it.

You are ready to remove the dried sludge when it can be picked up with a fork without excessive sand sticking to the underside. Forks are used instead of shovels to avoid removing too much sand. Wheelbarrows, trucks, tractors, or carts may be used to move the dried material. The digested sludge may be used for fertilizer or fill on approved dumps or in low-lying areas.

Don't allow trucks or other heavy equipment on the beds as they may crush and clog the underdrains. Another maintenance duty is draining all sludge lines to prevent hardening and freezing in the winter months. Also, all outer walls of the beds, valves, and sluice gates must be kept watertight to prevent wet sludge from leaking onto the beds during drying periods.

SECONDARY TREATMENT

At very large treatment plants, sewage undergoes further treatment known as the secondary treatment. This treatment aims at the oxidation of the sewage solids that have already been treated and are now soluble or finely divided. There are 5 different secondary treatment processes: (1) filtration, (2) secondary settling, (3) activated sludge, (4) contact aeration, and (5) subsurface irrigation. The use of oxygen is the major difference between the primary treatment of separating and treating solids and the secondary treatment processes.

Filtration

The trickling filter is the most common secondary treatment unit used in separating solids. The filter is an artificial bed of stone or slag 3 to 8 feet deep, held by a structure of concrete, brick, or wood. (See fig. 5–7.) The settled sewage is sprayed intermittently at set intervals on the top of the stones. It spreads over the stones and trickles down through the bed to be carried away in underdrains. The floor of the filter is usually made of concrete and supports and contains the underdrains. Air throughout the bed is provided at all times by openings in the walls or vent pipes which carry air from above the surface into the depths of the bed. The sewage is distributed over the top of the filter by spraying nozzles or by movable distributors.

The rough, broken stones attract the solids in the sewage and a gelatinous film develops. As the other sewage passes through, the film retains a lot of the organic matter and it is oxidized. The suspended matter will, from time to time, slip off the rocks and be carried away. This

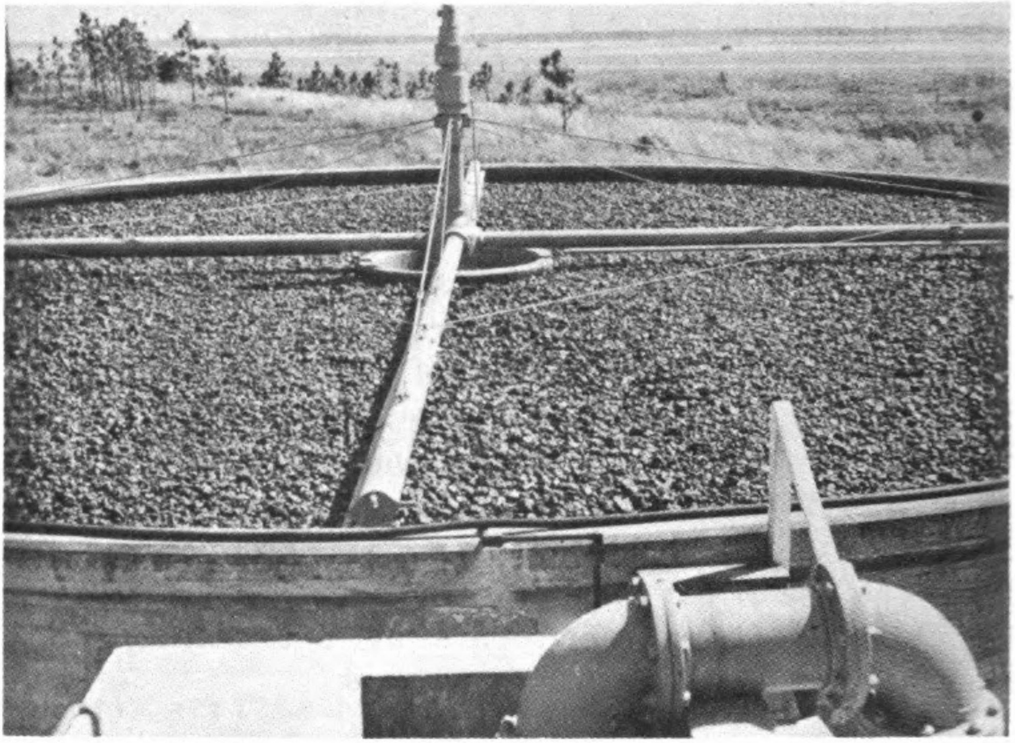


Figure 5-7.—Trickling filter.

is called unloading and occurs periodically, especially in the spring of the year.

In some cases the sewage is filtered through sand following primary settling or other treatment. The sand filter also serves as a method for the disposal whereby the sewage passes into the ground water and there is no surface effluent. The filter removes suspended solids mechanically by straining and also oxidizes them by action of bacterial films on the sand grains.

If a clean quartz sand area is available, it may be used as a filter bed. Otherwise sand is placed from 2 to 4 feet in depth in a rectangular or square bed. Lateral underdrains are placed on the bottom of the filter or in shallow trenches in the floor.

The sewage is applied at a relatively rapid rate for a short period of time. It is distributed from a temporary storing space called a dosing tank. It goes through troughs which have openings at several points. These troughs are laid on the filter beds.

The dosage varies from 1 dose every other day to 3 doses daily. The bed must drain thoroughly and the flow in the underdrains must be very low before the filter is used again. This is to permit thorough bed aeration.

Secondary Settling

In some plants, the sewage goes from the trickling filters through secondary sedimentation tanks. These tanks are similar to the primary plain sedimentation tanks, except that they are usually more shallow. They are operated in the same manner.
sludge is developed by continuously agitating sewage in hours. The sludge from the tanks is disposed of with the sludge from the primary tanks.

Activated Sludge

Another secondary treatment to remove and treat suspended solids is the activated sludge process. Activated sludge is developed by continuously agitating sewage in the presence of oxygen. It becomes an active biological material composed of numerous organisms. Activated sludge absorbs dissolved organic material and also frees sewage from its dissolved and suspended impurities. Most important of all, it produces organic substances called enzymes, which change objectionable matter to more stable substances.

In this process the sewage receives primary settling and then is mixed with activated sludge to form a mixed liquor. It next receives prolonged aeration in an aeration tank. In some plants, compressed air is admitted through diffuser plates or tubes in these tanks.

In other plants, mechanical aerators use impellers, revolving disks, or brushes for spraying sewage into the air or for pulling air down into the sewage. A period of

8 hours is desirable for diffused aeration, and 12 hours for mechanical aeration.

After this, the mixed liquor goes to a final-settling tank. The solids settle at the bottom and filter the sewage as it passes through. This process will remove 90 to 95 per cent of the suspended solids. The liquid is usually discharged without further treatment. The sludge at the bottom of the tank contains a larger proportion of nitrogen and has a greater fertilizing value than that produced by any other form of tank treatment. Some of it is returned to the mixing channel for use with raw sewage.

Contact Aeration

Another method of oxidizing and separating the solids is contact aeration. This process is comparable to the trickling filter treatment. The sewage is brought in contact with stationary cement-asbestos plates on which a biological film develops. Air is blown through the contact section from perforated pipes mounted below the plates (fig. 5–8).

Sludge is removed from contact aerators about once every 4 hours and returned to the raw-sewage flow. The

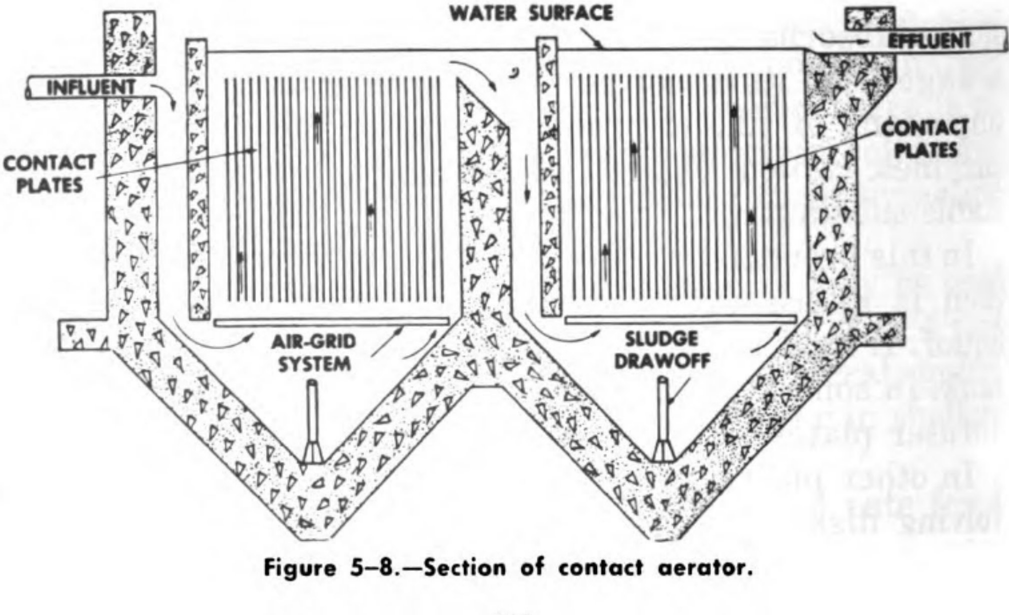


Figure 5–8.—Section of contact aerator.

sewage goes on from the contact-aeration tanks to settling tanks.

Subsurface Irrigation

The last of the secondary treatment processes is a disposal process, subsurface irrigation. This is the disposal of septic tank sludge through tile lines in loose and porous soil. The tile is laid in the ground with open joints. Fiber pipe lengths of 5 to 8 feet with holes bored in the lower portion of the pipe may be used for drain lines. The tile is laid on a bed of screened coarse gravel 6 inches deep with 3 inches of coarse gravel around and over the pipe.

CHLORINATION

Chlorine is used at sewage plants to control odors, to facilitate treatment, and to disinfect the final effluents. The principles involved in the chlorination of water are the same as those in sewage chlorination.

Either liquid chlorine or sodium hypochlorite can be used. Careful attention to proper operating and maintenance conditions is important. The temperature in the chlorinating room must be maintained at approximately 70°. The chlorinator and gas line cannot be exposed to cold drafts from open windows or doors. The chlorine cylinders must not be placed near heaters or in direct sunlight. The gas lines must be kept high with a constant slope upward from the cylinder to the chlorinator.

The rate of chlorine withdrawal from each 150-pound cylinder must not exceed 35 pounds for 24 hours. This is to prevent excessive cooling and pressure reduction in the cylinders. If the rate is exceeded, connect two or more cylinders in a parallel line.

You have to be careful in handling the chlorination equipment. Chlorine is dangerous. Play safe and watch what you're doing. Also take good care of the equipment so that it does its job properly.

LABORATORY ANALYSIS

Sewage is sampled and several types of analyses are made to find the strength and composition of the sewage, to control the various treatment processes, to determine the efficiency of the processes, to determine the actual results of treated-sewage discharge, and to compile records and data for future use.

You have to collect representative samples if you want your study to be accurate. For some tests, grab samples are taken by sampling sewage one time at one point. In most cases a composite sample is made. Individual samples are gathered at regular intervals in a 16 to 24 hour period. They are poured into a container which is kept cool or refrigerated. The contents of the container is stirred before any is removed for tests. The types of tests to be made and the records to be maintained are determined by the officers in charge of each installation.

DISPOSAL

In some instances the final effluent is aerated before it goes to disposal. This is usually accomplished by passing the effluent down an outdoor step aerator.

The common method of disposal is to send the treated sewage through surface or submerged pipes into a stream or other body of water. This dilutes the sewage.

If a stream is unavailable, disposal on land may be done by sending the sewage into a dry stream bed or into an irrigation ditch. Sometimes ponds and cesspools are utilized.

SAFETY PRECAUTIONS

There are several precautions that you can take to remain safe and healthy. Most important is being safety conscious and remembering that precautions prevent accidents, and carelessness kills men.

It's important to keep your hands and clothing clean to help prevent body infection. If you get any cut, burn, or injury while on the job, get first aid or medical treatment at once. If your hands are chapped, burned, or the skin is broken, wear rubber gloves at work. If possible, don't touch the sewage or liquid sludge with your hands. In the laboratory, don't drink water from the laboratory glassware. Don't eat lunch there. Before you shove off from the lab, whether to your quarters or to chow, wash your hands and face thoroughly with plenty of soap and hot water.

There are many mechanical hazards in a plant. Observe the safety railings around manholes, open tanks, and machines. Don't mess around with the protective guards on moving parts. If you are lubricating or repairing a machine, make sure that no one is going to start it while you are still working on it. If necessary, remove all the fuses. If you are going into a sewer or pit, be careful of the slippery surfaces and the gas fumes.

Gas fumes are a constant sewage plant hazard. There is danger of fire, explosion, or asphyxiation. Before you enter a sewer or pit, you should test with an explosimeter and an oxygen-deficiency lamp to see if there is any danger. When entering a tank or other danger area, wear rubber overshoes. Be especially gas conscious around sludge digesters and chlorine equipment.

QUIZ

1. When do you remove the grit from a grit chamber?
2. What type of screening is used to remove coarse and fine suspended solids in sewage?
3. How often should the cutting teeth of the comminutor be inspected?
4. How fast does sewage flow through a plain sedimentation tank?
5. What is the chief answer to septic tank odor control?
6. What is the recommended temperature for heated sludge digestion tanks?
7. How much sludge should be left for seeding purposes in a sludge digestion tank?
8. What is the recommended maximum thickness of sludge for drying on a sand bed?
9. What are the five secondary treatment processes?
10. What percent of the suspended solids is removed by the activated sludge process?
11. How often is sludge removed from the contact aerators?
12. Name three uses of chlorine at sewage plants.

CHAPTER 6

BASIC REFRIGERATION

The Utilities Man 1 or C is responsible generally for the installation, adjustment, and repair of refrigeration equipment, because these are jobs requiring the skill of a refrigeration mechanic. That is not to say that refrigeration is only a matter of passing interest to the Utilities Man 3 or 2. It is a subject that will assume increasing importance, if you intend to go on and seek advancement to the top petty officer rates.

You will be especially concerned—as a 3 or 2—with the basic principles and theory of refrigeration. The purpose, of course, is to prepare the background necessary to meet future requirements at the 1 and C level. Among other things, you should learn the heat theory of refrigeration, understand what takes place during the refrigeration cycle, and know the function of refrigerants in the refrigeration system. These and other topics will be discussed here. Because of the scope of the subject, air conditioning will be discussed separately, in the latter part of the chapter.

HEAT

The process of refrigeration involves the removal of heat from a confined space so that the temperature within that space is lower than that of the surrounding atmosphere.

To acquire a thorough knowledge of the principles of refrigeration, it is especially important that you understand certain physical laws on which the theory of refrigeration is based. One of these laws states that FLUIDS ABSORB HEAT IN CHANGING FROM A LIQUID STATE TO A GASEOUS STATE. In changing from a GAS to a LIQUID, fluids GIVE UP HEAT.

At this point we should explain that when the freezing or boiling points of a substance are reached, adding or subtracting heat will not cause further change in the temperature of the substance. A change in state will take place. The heat necessary to cause 1 pound of a substance to change its state at the boiling or freezing temperature is known as the "latent heat." In changing from a liquid to a gas, the heat necessary is known as the "latent heat of vaporization." In changing from a gas to a liquid, it is known as the "latent heat of condensation."

What may be termed the "law of temperature change" holds that, while the temperature at which a change in state occurs is constant during the change, it will vary directly with the pressure.

Heat will flow from a body of higher temperature to a body of lower temperature. Bear in mind that the greater the temperature difference between the two bodies, the faster will be the heat flow.

To help you understand the nature of heat, let us get straight on a few additional terms. First note that HEAT is a form of energy; ENERGY is the ability to do work. The term TEMPERATURE refers to a measure of the INTENSITY or level at which the heat energy exists.

The relative intensity or degree of heat (temperature) is usually measured with a thermometer. Two kinds of thermometers commonly used to measure heat are the Fahrenheit scale and the Centigrade scale.

In the Fahrenheit scale you have 180° between the freezing point (32°) and the boiling point (212°) of water. In the Centigrade scale you have only 100° between the same points (0° freezing; and 100°, boiling point).

Of course, a Centigrade reading can be converted to a Fahrenheit reading, and vice versa. To change a Centigrade reading to a Fahrenheit reading, multiply the Centigrade reading by 1.8 and add 32°. This can be expressed in terms of the following formula:

$$F = C \times 1.8 + 32$$

To change a Fahrenheit reading to a Centigrade reading, subtract 32 from the Fahrenheit reading and then divide by 1.8. The formula which applies here is:

$$C = (F - 32) \div 1.8$$

In addition to measuring the relative intensity of heat, it is also possible to measure its quantity. A common unit of measure of heat quantity is known as the British Thermal Unit (abbreviated Btu). One Btu is required to raise the temperature of 1 pound of pure water 1 degree Fahrenheit. The quantity of heat required to melt 1 pound of 32° F ice to 1 pound of 32° F water is 144 Btu's. The same amount of heat must be removed to change 1 pound of water at 32° F to ice at 32° F. Therefore, 1 ton of refrigeration is 144 Btu × 2,000 lbs or 288,000 Btu's. In practice, the time factor is included, and a STANDARD TON OF REFRIGERATION corresponds to heat absorption at the rate of 288,000 Btu per day. Thus, a 1-ton refrigeration unit will absorb 288,000 Btu per day, which is equivalent to melting 1 ton of ice in 1 day.

Heat, as a form of energy, cannot be destroyed. However, it can be transferred from one substance to another. Three methods of heat transfer include: conduction, convection, and radiation. In RADIATION, heat flows from a body in all directions as a wave motion. If two bodies of unequal temperature are placed close together, there will be a continual interchange of energy. However, the hotter body will radiate more energy than it will absorb, and the colder body will absorb more than it will radiate. Transfer of heat from the sun to the earth is an example of radiation.

In CONDUCTION, heat is transferred from one part of a body to another part of the same body. Heat flowing along an iron bar, one end of which is held in a fire, is a simple example of this process. Conduction occurs when the conductor is in actual physical contact with the source of heat and the point of delivery. Heat flows from the hot to the cold end of the bar by molecular activity.

CONVECTION involves the transfer of heat through a fluid (liquid or gas) body. Here the flow of heat is caused by the natural motion of the heated substance itself—whether liquid or gas. Take a pan of boiling water as an example. When heated the water becomes lighter, bubbles to the top of the pan and spreads heat. Transferring heat by this method is known as convection. In refrigeration, convection is the most important method of heat flow; it provides for the transfer of heat from a warm body to a cold body, using a liquid or gas as the heat carrier.

REFRIGERANTS

A REFRIGERANT is a medium by which heat is removed from the region being cooled and conveyed to a higher temperature level where the absorbed heat can be discharged.

What the refrigerant does is remove heat from the refrigerated compartment, changing into a gas; then the gas gives up its heat, outside the compartment, changing into a liquid again—returning to pick up more heat, and so on. It is by mechanical means, of course, that changes in the refrigerant's state are brought about. The changes in state occur over and over again, without changing the original composition of the substance (refrigerant).

Common refrigerants include ammonia, methyl chloride, and dichlorodifluoromethane. The latter, known as Freon-12, is the refrigerant most commonly used by the Navy. Ammonia, methyl chloride, and Freon-12 are in the category known as primary refrigerants. A PRIMARY REFRIGERANT is a refrigerant that cools by absorbing latent heat.

There are secondary refrigerants—as well as primary refrigerants. A SECONDARY REFRIGERANT is one that cools by absorbing sensible heat. Air is perhaps the most common secondary refrigerant used in refrigeration units. Brine and water are used as secondary refrigerants in some cases, as in ice making.

Freon-12

One of the primary desirable characteristics of Freon-12 is that it is nontoxic. The low-boiling point of Freon-12 is also one of several characteristics which makes its use desirable as a refrigerant for mechanical refrigeration systems. At atmospheric pressure, Freon-12 has a boiling point of —21.6° F. It requires so little heat to reach a gaseous state that it must be kept under pressure to be maintained as a liquid. At ordinary room temperatures, it is a liquid when under a pressure of about 70 to 75 pounds per square inch. It is shipped liquefied under pressure in steel cylinders. In a vaporous state, Freon-12 absorbs heat from substances around it to the extent that, when contained in the evaporator of a refrigeration system, it freezes particles of moisture coming in contact with the evaporator.

Freon-12 liquid or vapor is nonflammable and nonexplosive. These characteristics also make Freon-12 a desirable refrigerant. Its air mixtures are not capable of spreading a flame.

Speaking of desirable characteristics, Freon-12 is noncorrosive to metals commonly used in refrigerating apparatus. Too, it is an excellent solvent, proving very effective in loosening and removing particles of dirt, scale, and oil with which it may come in contact.

Pure Freon-12 is colorless and odorless in concentrations of less than 20 percent by volume in air; in higher concentrations, its odor resembles that of carbon tetrachloride.

VAPOR COMPRESSION REFRIGERATION SYSTEM

An elementary diagram of a typical vapor compression refrigeration system that is generally applicable to refrigerants used by the Navy is shown in figure 6–1. The principal parts of this type of refrigeration system include:

1. the COOLING COIL (or EVAPORATOR), where the refrigerant absorbs heat and boils to a gas;
2. the COMPRESSOR, where the refrigerant gas is compressed and its temperature raised so that it can give up its latent heat of vaporization;
3. the CONDENSER, where the latent heat in the gas is given up and is carried away by a cooling medium, thereby changing the gas to a liquid;
4. the EXPANSION VALVE, through which the pressure of the refrigerant liquid is reduced so that it can repeat its process of absorbing heat in the evaporator.

The cooling coil is located in or near the space where the cooling is to be accomplished. It is arranged to provide for natural or forced circulation of the secondary refrigerant or heat carrier. The function of the coil is to cool the secondary refrigerant so that it can continue its work of absorbing heat in the compartments or spaces being cooled. The liquid refrigerant in the coil is maintained at a low pressure which produces a refrigerant boiling temperature lower than the temperature of the secondary refrigerant. This temperature difference causes the heat to flow from the secondary refrigerant through the metal walls of the coil to the primary refrigerant. The liquid primary refrigerant is already at its boiling point but is capable of absorbing its latent heat of vaporization.

The secondary refrigerant, which gave up its heat to the primary refrigerant, is now capable of absorbing more heat and of carrying it back to the evaporator again.

The primary refrigerant which has been boiled to a gas in the process cannot absorb more latent heat until

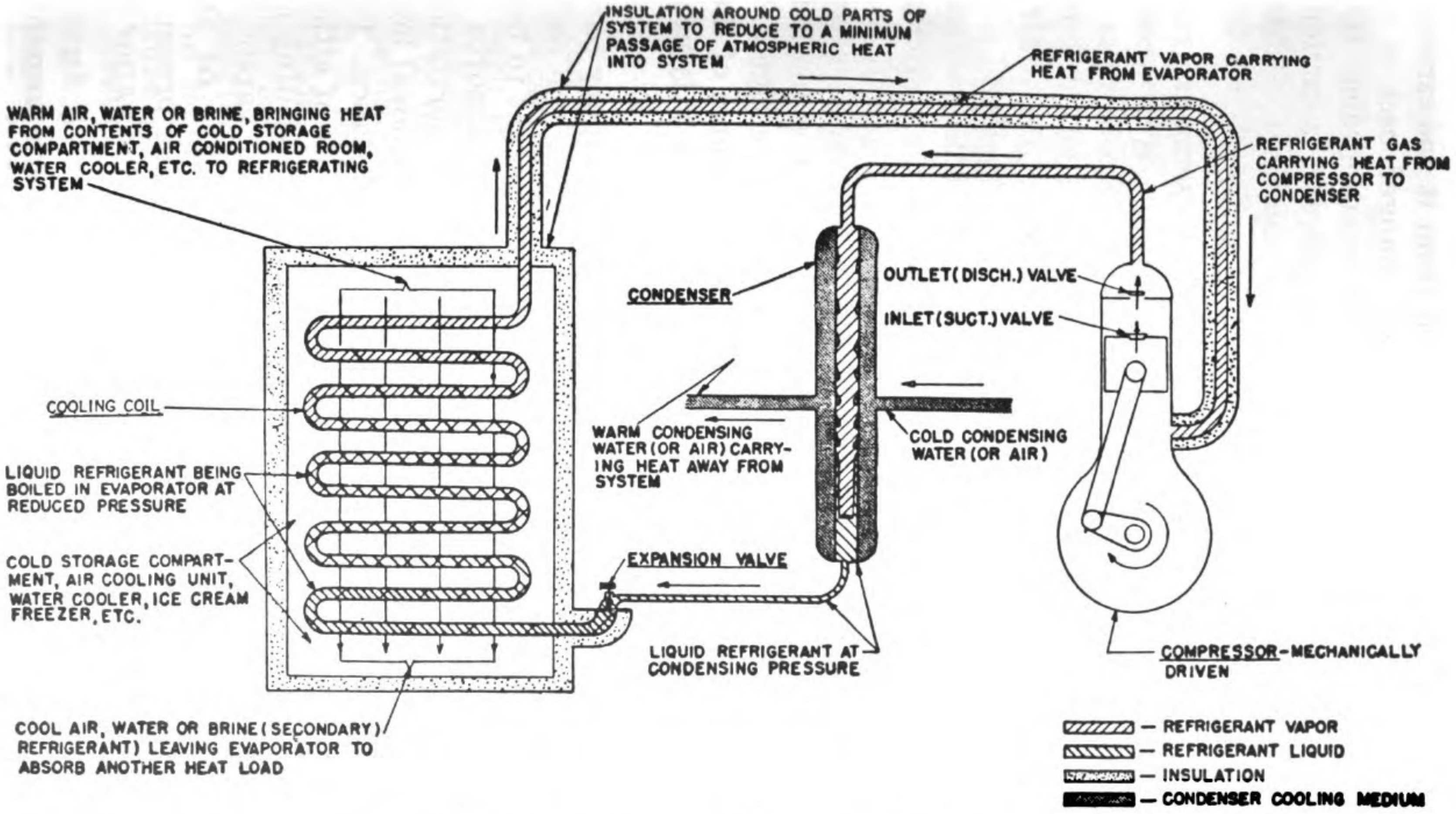

INSULATION AROUND COLD PARTS OF SYSTEM TO REDUCE TO A MINIMUM PASSAGE OF ATMOSPHERIC HEAT INTO SYSTEM
REFRIGERANT VAPOR CARRYING HEAT FROM EVAPORATOR
WARM AIR, WATER OR BRINE, BRINGING HEAT FROM CONTENTS OF COLD STORAGE COMPARTMENT, AIR CONDITIONED ROOM, WATER COOLER, ETC. TO REFRIGERATING SYSTEM
REFRIGERANT GAS CARRYING HEAT FROM COMPRESSOR TO CONDENSER
CONDENSER
OUTLET(DISCH.) VALVE
INLET(SUCT.) VALVE
COOLING COIL
WARM CONDENSING WATER (OR AIR) CARRYING HEAT AWAY FROM SYSTEM
COLD CONDENSING WATER (OR AIR)
LIQUID REFRIGERANT BEING BOILED IN EVAPORATOR AT REDUCED PRESSURE
COLD STORAGE COMPARTMENT, AIR COOLING UNIT, WATER COOLER, ICE CREAM FREEZER, ETC.
EXPANSION VALVE
LIQUID REFRIGERANT AT CONDENSING PRESSURE
COMPRESSOR-MECHANICALLY DRIVEN
COOL AIR, WATER OR BRINE (SECONDARY) REFRIGERANT) LEAVING EVAPORATOR TO ABSORB ANOTHER HEAT LOAD
▨ — REFRIGERANT VAPOR
▨ — REFRIGERANT LIQUID
▨ — INSULATION
■ — CONDENSER COOLING MEDIUM

Figure 6–1.—Typical vapor compression refrigeration system.

the heat absorbed has been removed from it and carried away from the system and the gas changed back to a liquid. Water or air constitutes the usual medium by which the heat absorbed by the refrigerant is carried away from the system. The water or air is available usually at temperatures between 40° F and 100° F.

In order that this water or air at these temperatures can serve to condense the refrigerant again, it is necessary that the pressure of the refrigerant gas be raised to a pressure at which its condensing temperature is higher than the temperature of the cooling water or air. The pressure to which the gas must be compressed depends on the temperature of the available cooling water or air into which the heat must flow, and the capacity of the condenser to transfer heat from the gas to the cooling medium. Therefore, the compressor must raise the pressure of the refrigerant gas to a point somewhat higher than the pressure corresponding to a refrigerant condensing temperature equal to the temperatures of the condenser cooling medium. Figure 6–2 shows a typical air-cooled condensing unit.

In the cycle as discussed to this point, the higher temperature substance (air or liquid) surrounding the cooling coil causes the low-pressure liquid refrigerant to boil or evaporate. In doing this, the refrigerant absorbs a quantity of heat equal to its latent heat of vaporization from the surrounding substances. This heat removal lowers the temperature of the surrounding substance. The compressor meanwhile starts to operate, because of either an increase in pressure or in temperature, depending on the type of control. It draws the heat-laden vapor or gas from the cooling coil. The piston strokes of the compressor reduce the volume and increase the pressure and temperature of the low-pressure heat-laden vapor or gas.

Now, continuing the cycle, the high-pressure vapor is forced into a condenser at a temperature higher than

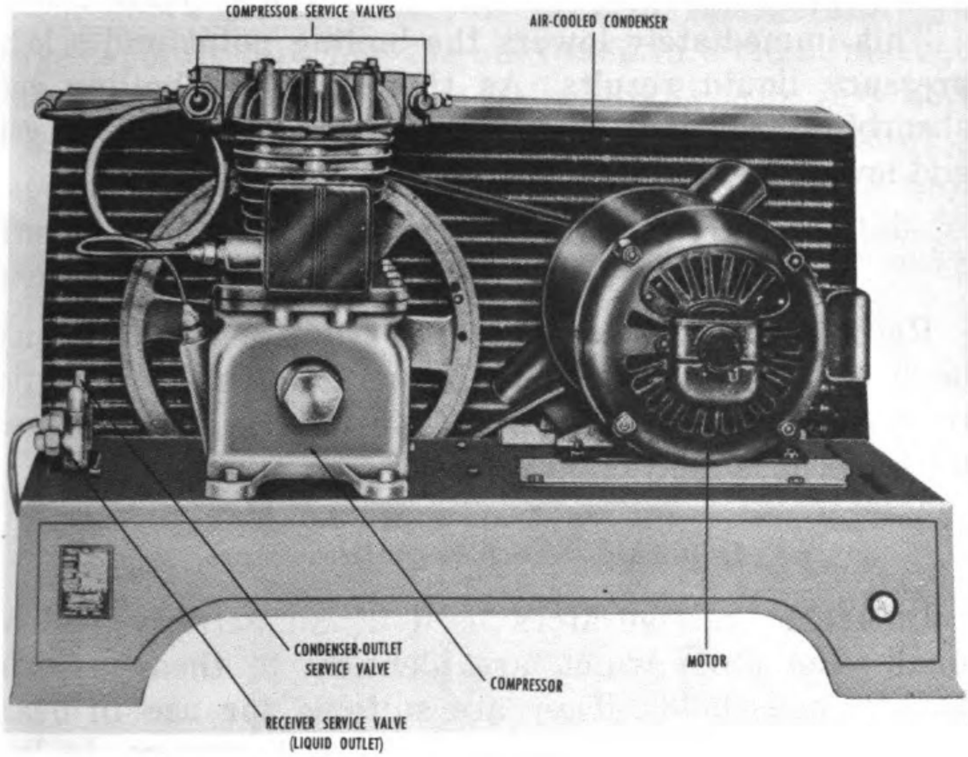

COMPRESSOR SERVICE VALVES
AIR-COOLED CONDENSER
CONDENSER-OUTLET SERVICE VALVE
MOTOR
COMPRESSOR
RECEIVER SERVICE VALVE (LIQUID OUTLET)

Figure 6–2.—Typical air-cooled condensing unit.

the condensing medium of air or water. Because of the temperature difference, the heat from the gas passes through the metal walls of the condenser tubes into a cooling medium flowing past the surfaces. The refrigerant cools to the temperature corresponding to its condensing temperature at the pressure existing in the condenser. Then it condenses and gives up its latent heat of condensation. It drops to the bottom of the condenser as a high-pressure liquid refrigerant and is ready to perform its function in the cooling coil again.

The liquid refrigerant must drop to the evaporating pressure again before it can repeat the process of absorbing heat from the secondary refrigerant. It travels through a liquid line to an expansion valve between the condenser and the cooling coil. This valve controls the flow of refrigerant into the cooling coil. As the refrigerant passes through the valve opening its pressure is reduced.

This immediately lowers the boiling point and a low-pressure liquid results. As this liquid is boiling and absorbing heat, it is changing its state to a vapor or gas and lowers the temperature of the cooling coil.

REFRIGERATORS

Refrigerators commonly used at Navy installations may be broken down into three general classes: domestic, reach-in refrigerators; commercial, reach-in boxes; and walk-in boxes. Let us take a brief look at each class.

Domestic, Reach-In Refrigerators

DOMESTIC refrigerators used at an activity will be small-sized units which are identical to those used in civilian households. They are suitable for use in quarters or hospital diet kitchens for food storage, in laboratories for preservation of serums and biologicals, and in various other places for similar purposes.

Domestic refrigerators currently available for use at Seabee units include a 10-cu ft electric model and an 8-cu ft kerosene model.

The electric model has a white enamel interior and exterior finish steel cabinet, with a 1.2 cu ft frozen food compartment and vegetable bin. The storage compartment is designed to maintain a temperature range of 35° to 50° F. The unit is provided with temperature controls, ice trays, and shelves. It can be obtained with either 1 or 2 doors. The electric model measures approximately 40 inches in width, 30 inches in length, and 68 inches in height.

The 8-cu ft kerosene refrigerator is used where electric power is not available. It is similar to the electric model but uses kerosene as a fuel. It also differs from the electric model in that it uses an aqueous solution of ammonia and hydrogen as a refrigerant.

Commercial, Reach-In Boxes

The COMMERCIAL REACH-IN TYPE of refrigerator is a large capacity unit like the ones seen in civilian markets and restaurants. At Seabee units this type is very suitable for mess halls or other places where a larger storage capacity is needed than is afforded by the domestic unit. The commercial-type box can also be used in hospitals for storage of biologicals and other medications.

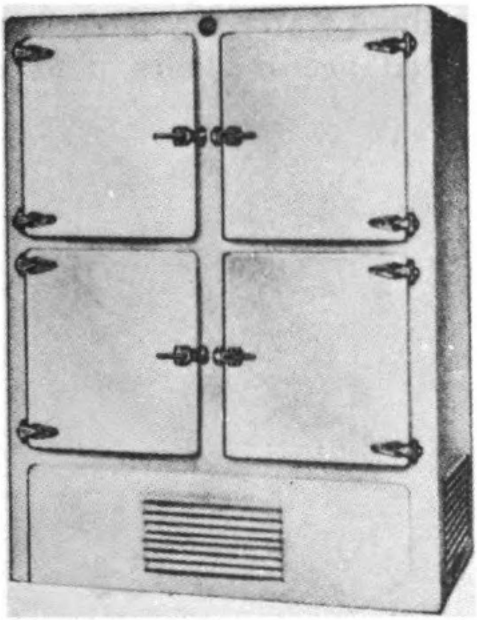


Figure 6–3.—Commercial, reach-in refrigerator.

A 30-cu ft electric model, presently available for Seabee use, is illustrated in figure 6–3. This unit has an insulated enameled-steel or aluminum cabinet and storage compartment with rustproof, grid-type shelving. It uses Freon-12 as the refrigerant. Although present models have 4 doors, older models with only 2 doors are still being used.

Walk-In Refrigerators

The WALK-IN REFRIGERATOR essentially is an insulated space or room. It may be built into a building as part of the building itself. Then, again, it may be a prefabricated type of room which, although located within a building, is not actually a part of the building. Walk-in refrigerators are used primarily for the storage of meats, dairy products, vegetables, fruits, and frozen foods. They are similar to the walk-in coolers used in civilian stores and hotels.

A common type of walk-in box is illustrated in figure 6–4. This box provides 150 cu ft of space, is mounted on wood skids, and is equipped with towing and lifting rings. Other features include a structural steel frame, insulated metal walls, hinged access doors, and hardwood floor racks.

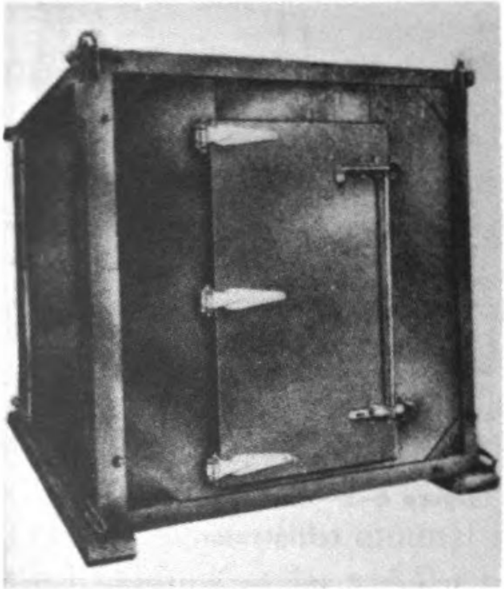


Figure 6–4.—Walk-in refrigerator.

The 150-cu ft model normally uses an electric motor as the source of power for its air-cooled, Freon-type, condensing unit and compressor. However, it can be obtained with a detachable, plug-in type refrigeration unit, which is powered by a gasoline engine. This type is designed for tropical service.

In addition to the 150-cu ft model, three larger sizes of walk-in refrigerators are available, having capacities of 600, 1,800, and 4,000 cu ft. These are prefabricated, demountable-type refrigerators and may be thought of in terms of refrigeration warehouses. They are constructed of insulated steel-covered panels, zinc-coated inside, and painted outside.

Figure 6–5 shows a plug-in type unit which is used in prefabricated refrigerators. More than one refrigeration unit may be necessary, depending on the capacity of the box; only one unit is required for a 600-cu ft model. It is an integral unit, having an angle iron frame and an insulated metal insert designed for attachment to the "D" panel used in demountable-type refrigerators. This refrigeration unit is equipped with an air-cooled condenser, evaporator, and compressor using Freon-12 refrigerant, air circulating fans, receiver, and panel mounted controls. The unit operates on 220-volt, a-c, 60-cycle, 3-phase electric service.

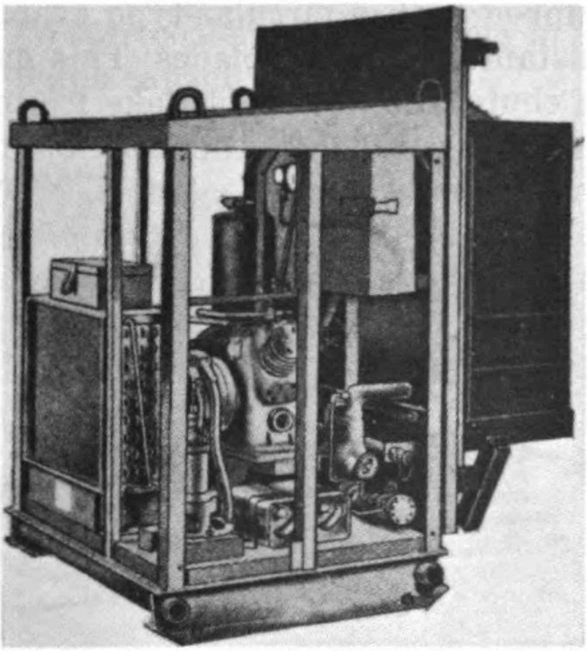


Figure 6–5.—Refrigeration unit.

The 600-, 1,800-, and 4,000-cu ft capacity refrigerators all are approximately 12′10″ wide and 7′6″ high. The approximate length and number of doors for each unit is as follows:

Capacity	*Length (Approx.)*	*No. of doors*
600 cu ft model	8′11″	1
1,800 cu ft model	24′3″	2
4,000 cu ft model	54′11″	4

OTHER REFRIGERATING EQUIPMENT

Other types of refrigerating equipment which you may find at your installation, in addition to the refrigerators we have been talking about, include a FLAKE ICEMAKING MACHINE. The Navy uses a self-contained, automatic machine, equipped with a circular-type evaporator with corrosion-resistant ice-cutting blades. This model has an ice discharge chute. One model of flake ice machine has a wood cabinet and a 1,000-lb. capacity, built-in storage bin. Some models have metal cabinets, in which case materials are furnished for construction of an insulated, metal-lined wood-framed 1,000-lb. capacity storage bin.

A most desirable piece of equipment at any Seabee unit is the ICE CREAM PLANT. Two sizes are currently available.

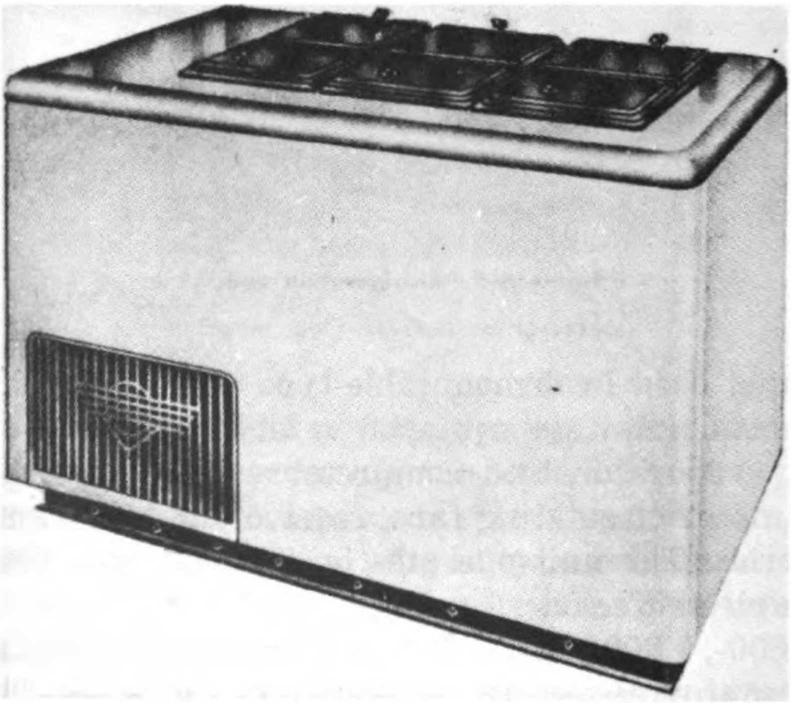


Figure 6–6.—Refrigerated ice cream dispensing cabinet.

One has a 6-quart freezing unit, which has a hardening and dispensing capacity of 20 gallons. The other has a 20-quart freezing plant with a hardening and dispensing capacity of 80 gallons. Both are self-contained, skid-mounted units. Each plant is electrically powered.

Ice-cream DISPENSING CABINETS, likewise, are available. (See fig. 6–6.) The cabinets are equipped with steel cans to afford storage of either 30, 35, or 40 gallons of ice cream. They are electrically operated and have a corrosion-resistant top, lids, and hardware.

The water cooler or drinking fountain is the familiar "scuttlebutt." Water coolers are available in three sizes: 20, 75, and 150 gph capacity.

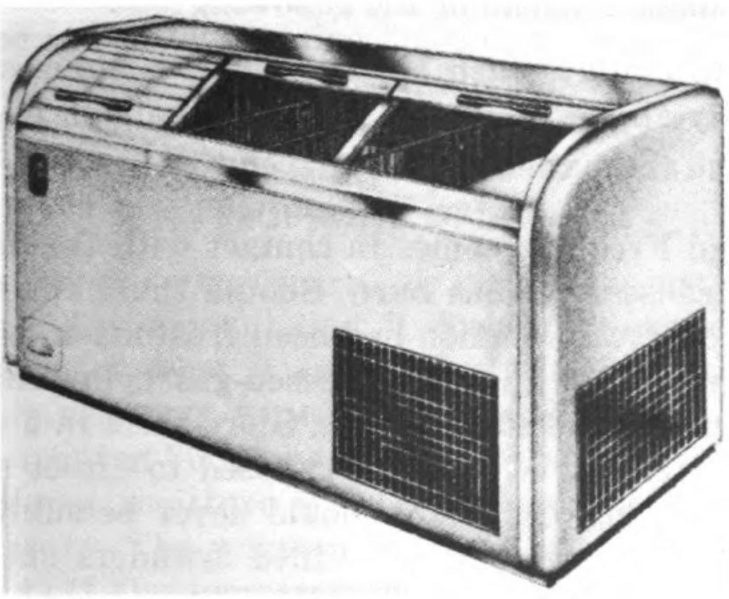


Figure 6–7.—Bottled beverage cooler.

You will recognize the bottled beverage cooler illustrated in figure 6–7 as the type commonly found in grocery stores and other commercial establishments. According to size, these coolers hold approximately 528 or 768, 12-ounce bottles. The coolers have corrosion-resistant hardware, removable wire compartment dividers, apron, and covers.

Each refrigerator is designed to work with a particular type of gas. Most refrigerators with which you will work will use Freon-12. However, ammonia, methyl chloride, or sulfur dioxide may be used as a refrigerant. You must be very certain not to place the wrong gas in a refrigerator; to do so might ruin the refrigerating system or cause an explosion.

Always wear goggles when you loosen a connection in which Freon-12 is confined. Contact with the eyes may cause serious injury by freezing the moisture in the eyes. If there is contact with the eyes, go to a doctor as soon as possible. Avoid rubbing or irritating the eyes. First aid treatment consists of the following:

1. Immediately wash the eyes with copious amounts of fresh water (warm water if available).
2. Take the patient to the dispensary.

If liquid Freon-12 comes in contact with the skin it is likely to cause a serious burn. Should this happen, treat as if the contacted portion had been frostbitten or frozen.

It is important that compressed-gas cylinders of refrigerants be handled with care. Store them in a cool dry place, where they will not be exposed to direct sunlight for long periods. Cylinders should never be subjected to temperatures above 125° F. Filled cylinders should not be dropped, altered, or repaired, and should not be bumped violently against one another.

Do not use cylinders as rollers, supports, or for any purpose other than to carry refrigerant. Do not let a direct flame or jet of steam come in contact with any part of a compressed-gas cylinder. Never mix compressed gases. Always keep a protective cap on valves not in use.

The need for safety in refrigeration work cannot be overemphasized. By endeavoring to practice safety in your work you will be doing both yourself and the Navy a worth-while service. In case you want to devote a little time on your own to a study of safety, you should find beneficial Chapter 25, "Refrigeration," of *U. S. Navy Safety Precautions*, OPNAV 34P1.

AIR CONDITIONING

Air conditioning is the process by which the temperature, moisture content, movement, and quality of air in an enclosed space is maintained within desired limits. The purpose of air conditioning is to provide comfort for people, to provide atmospheric conditions desirable in the manufacture of certain products, or to provide conditions essential for the proper functioning of certain facilities.

At advanced bases, air-conditioning equipment is frequently installed in photographic laboratories. It may be installed in special training buildings, bombsight storage rooms, drafting rooms, hospitals, and similar locations where controlled air conditions are needed.

PROPERTIES OF AIR

At a given temperature, air can hold just so much moisture. The amount that it does hold, expressed as a percentage of what it can hold at that temperature is called its RELATIVE HUMIDITY. Thus, a relative humidity of 90 percent at 76° F means that the air holds 90 percent of whatever moisture it is capable of holding at that temperature. The warmer the air, the more moisture it can hold. If the temperature of the air just mentioned is raised from 76° F to 86° F the relative humidity would decrease from 90 percent to 64 percent, because the capacity of the air to hold moisture has been increased. Charts have been worked out to show properties of water vapor in air at various temperatures.

In the example just given, the amount of moisture in the air has not changed; only the capacity of the air to hold water vapor has been changed. The actual amount of water vapor in air is usually expressed in grains per pound of dry air and is called SPECIFIC HUMIDITY or

HUMIDITY RATIO. A pound of dry air containing 70 grains of moisture has a humidity ratio of 1/100 pound of water per pound of dry air (7,000 grains equal 1 pound). The relative humidity of air containing this amount of moisture depends upon the temperature.

If air with a given moisture content is cooled to a temperature where the moisture saturates the air, that temperature is called the DEWPOINT. When cooled beyond that temperature, the air cannot hold the moisture, and the excess moisture precipitates out of the air as condensate in the form of dew, fog, mist, or droplets. In air conditioning, the excess moisture forms on the cold evaporator coil.

The term DEHUMIDIFICATION refers to the process of the removal of moisture from the air. This can be done by lowering the temperature below the dewpoint or by absorption by such materials as silica gel.

Except in cases of chemical absorption of moisture from the air, dehumidification depends upon reducing the air temperature. When air leaves the evaporator coil of an air-conditioning unit, the specific humidity is lower (since moisture has been removed), but the relative humidity is higher (since the air has been cooled and its capacity to hold moisture has been reduced). When this cool air is blown into a room, the cool air absorbs heat from the air in the room. As the temperature of the cool air rises, its relative humidity decreases, and moisture from the air in the room is also absorbed in the cool air. Cooling and dehumidification are thus possible at the same time. If there is not enough heat in the room from people, lights, and conduction through the walls to keep the room up to the desired temperature, then the air leaving the conditioner must be artificially heated by the reheater coil. In humid climates with relatively low outside temperatures, it is often necessary to dehumidify and reheat.

If air passed through the evaporator coil is cooled to as low a temperature as the coil has capacity to attain, but the air is dry and does not have enough moisture in it to become saturated at the temperature attained, no dehumidification will result. As a rule, air that is dry does not have to be dehumidified to maintain a low relative humidity inside the conditioned room. In hot, dry climates, therefore, reheating is seldom necessary.

AIR-CONDITIONING UNITS

The principles just discussed are the basis for the design of the air conditioner shown in figures 6–8A and 6–8B. This unit is one type used by the Seabees. It is an automatic, self-contained unit described as a dehumidifier and cooler. The unit is fully enclosed in an insulated sheet steel cabinet with removable panels and top horizontal discharge of conditioned air. The principal parts are a V belt-driven, two-cylinder compressor and compressor-type fan; a 5-hp, 220-volt, a-c, 60-cycle, 3-phase motor; air-cooled condensers using Freon-type refrigerant; receiver, evaporator, reheater coils with face and bypass dampers; multiblade, variable-capacity, circulating fan regulated by two interchangeable V belt-driven pulleys; a $\frac{1}{2}$-hp, 110/220-volt, 60-cycle, single-phase motor (to power the circulating fan) ; and an air filter and control panel with a three-position switch. An extra charge of refrigerant, a tool box, and maintenance tools accompany the unit.

Theory and General Operating Procedures

The refrigeration system of the air-conditioning unit just described is based upon the refrigeration cycle shown in figure 6–1. Liquid refrigerant (Freon-12) is fed into the tubes of the evaporator coil. The heat absorbed from cooling and dehumidifying the air makes this liquid boil or evaporate into a gas, which is sucked into the compressor and pumped to the condenser. Air (in a separate circuit from the conditioned air circuit) is drawn from outside through the condenser; this air picks up the heat, which was originally removed by the evaporator, from

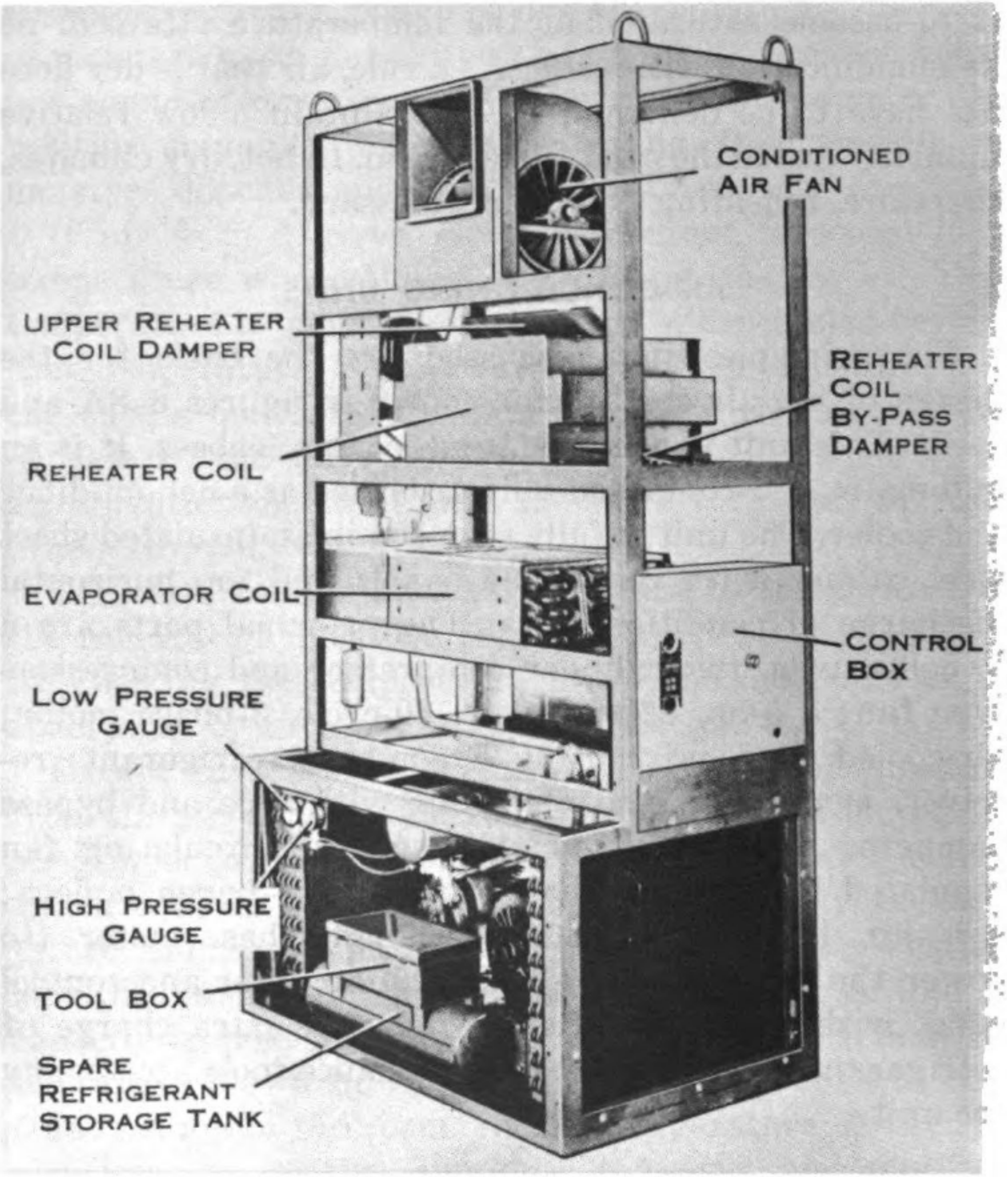


Figure 6–8A.—Front view of air-conditioning unit with panels removed.

the condenser. The heat is discharged outside. When the refrigerant gas inside the condenser tubes has the heat removed, the gas condenses to the liquid state and flows into the receiver to accumulate. The expansion valve automatically controls the flow of this liquid refrigerant from the receiver into the evaporator according to the cooling demand. Reheating is accomplished by diverting some of the hot refrigerant gas to the reheater coil instead of to the condenser.

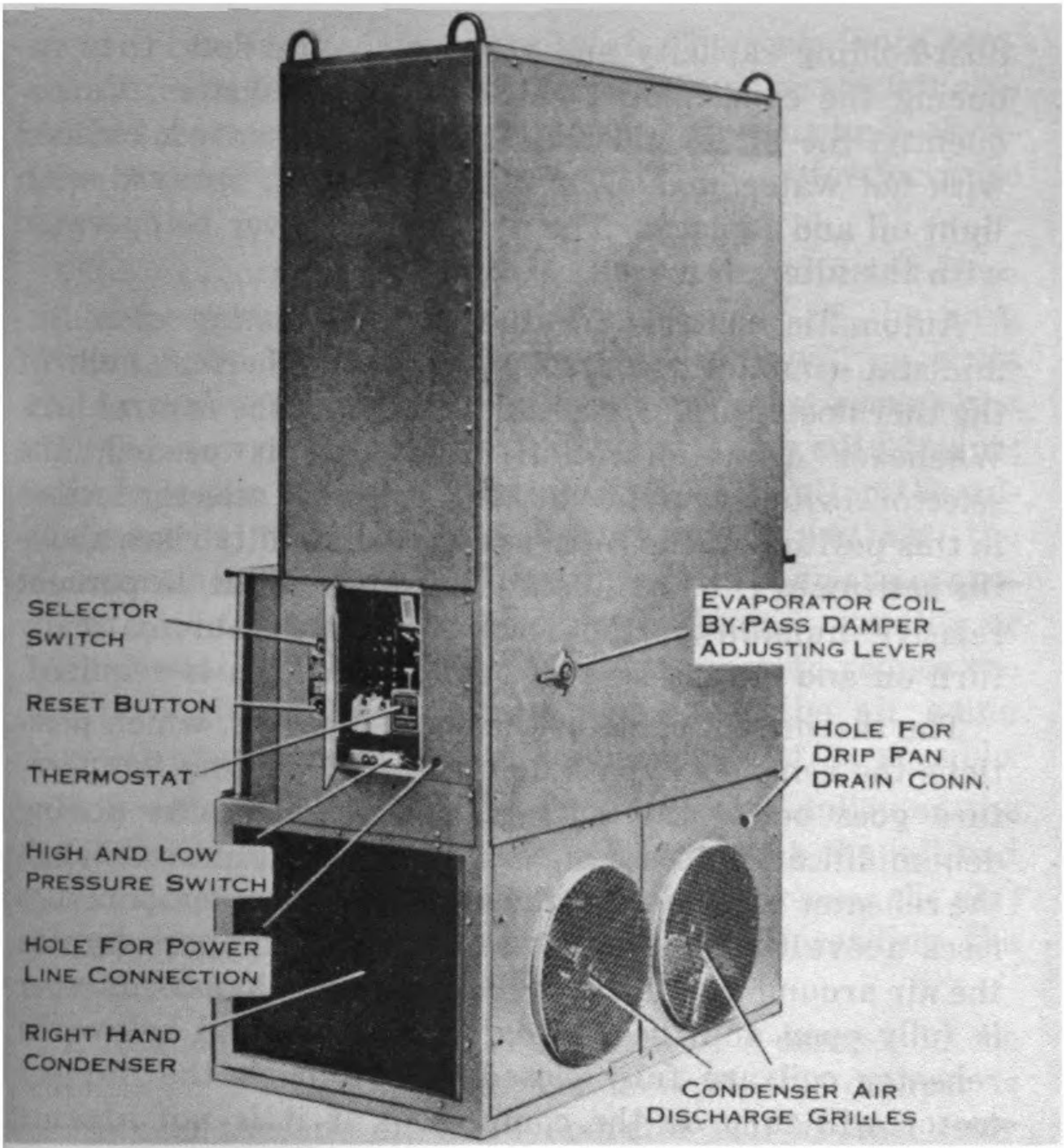

SELECTOR SWITCH
RESET BUTTON
THERMOSTAT
HIGH AND LOW PRESSURE SWITCH
HOLE FOR POWER LINE CONNECTION
RIGHT HAND CONDENSER
EVAPORATOR COIL BY-PASS DAMPER ADJUSTING LEVER
HOLE FOR DRIP PAN DRAIN CONN.
CONDENSER AIR DISCHARGE GRILLES

Figure 6–8B.—Rear view of air-conditioning unit.

For the conditioned air circuit, air is drawn from the room, and a small amount for ventilation is drawn from the outside. The mixture passes through the evaporator coil, where it is cooled and dehumidified. If room conditions so require, the mixture passes through the reheater coil; otherwise, the reheater coil is automatically bypassed. All of the returned and outside air passes through filters composed of series of wires coated with oil to which dust adheres. As the filters become dirty, they lose their dust-holding capacity and restrict the air flow, thus reducing the conditioning capacity of the system. Consequently, the filters must be frequently removed, cleaned with hot water, steam, or compressed air, sprayed with light oil and replaced. The unit should never be operated with the filters removed.

Automatic controls for the unit, consisting of a humidistat (humidity controller) and the thermal bulb of the thermostat are located on the back of the control box. Whenever dehumidification or cooling is needed, the selector switch should be at RUN. With the selector switch in this position, if the room's relative humidity rises above the setting of the humidistat (normally set at 45 percent relative humidity), the compressor will automatically turn on and run as long as dehumidification is required.

The thermostat controls the damper motor, which positions the reheater bypass dampers. If the room temperature goes below the setting of the thermostat during dehumidification, the dampers divert enough air through the reheater coil to reheat the air. If the room temperature rises above the thermostat setting, the dampers bypass the air around the reheater coil. When the bypass damper is fully open and the two dampers above and below the reheater coil are fully closed, a switch on the damper motor will turn on the compressor if it is not already running under the demand of the humidistat.

Adjusting the Controls

The humidistat is factory set at 45 percent relative humidity and seldom needs to be adjusted. Access to the humidistat is gained by removing the right hand filter and, if there is a return duct, by opening the access door in the duct. Adjustment is made by a lever at the bottom of the control box. Moving the lever to the left sets the unit for lower relative humidity, and moving the lever to the right sets it for higher humidity.

The thermostat is inside the control box. The adjustment screw is atop the thermostat. The scale, with temperatures in Fahrenheit and Centigrade, is on the left side of the thermostat cover. Turning the adjusting knob clockwise raises the temperature setting; counterclockwise lowers it.

The evaporator coil bypass damper is adjusted by a dial-type damper lever on the back panel of the unit. Turning the lever clockwise as far as it will go shuts the damper; counterclockwise opens it. Do not remove the thumb screw on the damper lever to make an adjustment; merely loosen it, but be sure to tighten it after the adjustment is made. In hot climates or hot weather, the damper should be shut to force the air through the evaporator coil for maximum cooling. In humid climates or humid weather, the damper should be open to reduce the air through the evaporator coil, so that the air going through may be cooled to as low a dewpoint as possible.

Air volume is adjusted by the adjustable pulley on the conditioned air-fan motor, accessible through the left end panel. Increasing the pitch of the pulley increases the air; decreasing the pitch decreases the air. Spreading the grooves decreases the pulley pitch.

Entrance of outside air is adjusted by a damper in the outside air duct connection. The lever on this damper is similar to the one on the evaporator coil bypass. Only enough air should be admitted from the outside to prevent objectionable odors in the room. Outside air is usually hotter and more humid than return air from the room and consequently places a heavier load on the unit. Leaving the damper about one-third open normally allows the proper amount of air to enter.

The re-set knob is located in the cover of the control box, below the selector switch. The compressor motor is protected against overload by a thermal element which will open the overload relays in the control box. The circuit is re-set by turning the re-set knob counterclockwise. The most frequent cause of an overload is low voltage.

Frequent overload trouble may mean that the wires to the unit are too small.

OTHER UNITS

The unit described in preceding paragraphs is only one of the types with which you may come in contact in the course of your duties. As manufacturers produce new and improved types of cooling and dehumidifying equipment, the Bureau of Yards and Docks stocks the type which most closely fills the need for Bureau activities. Two principal differences between most new models and the one described are: (1) the new models have greater cooling capacity; and (2) the condenser is cooled by water rather than by air.

The basic principles of air conditioning are the same for all types of units. The manufacturer's manual accompanying the equipment should be studied carefully; use it as your guide in duties concerning the operation and care of a particular unit.

QUIZ

1. What does the process of refrigeration involve?
2. What is latent heat?
3. What is heat?
4. How is heat quantity measured?
5. How much heat (in Btu's) is required to melt 1 pound of 32° F ice to 1 pound of 32° F water?
6. What are the three methods of heat transfer?
7. What name is given to the method of heat transfer by heat waves?
8. In refrigeration, what is the most important method of heat flow?
9. What refrigerant is used most by the Navy?
0. What is a primary refrigerant?
1. What is a secondary refrigerant?
2. What is a refrigerant?
13. Name the four basic parts of a vapor compression refrigeration system.
14. What is the boiling point of Freon-12 (at atmospheric pressure)?
15. Where should compressed-gas cylinders of refrigerants be stored?
16. What is relative humidity?
17. What is specific humidity?
18. To what does the term dehumidification refer?
19. What valve on an air-conditioning unit automatically controls the flow of liquid refrigerant from the receiver into the evaporator?
20. What are two principal differences between new models of air-conditioning units and older models?

CHAPTER 7

ENGINES, PUMPS, AND COMPRESSORS

Internal combustion engines serve a very useful purpose in the utilities field. Because they are commonly used as a means of supplying the power necessary to drive regular utility equipment, internal combustion engines play a major role in the accomplishment of various tasks.

An internal combustion engine is a machine that produces mechanical energy by burning fuel within a confined space (the engine cylinder). The term applies to both gasoline and diesel engines.

While the Utilities Man does not have to be a mechanic he should have a knowledge of the basic principles underlying gasoline and diesel engine operation. This is important since the UT has to operate and maintain the engine used to drive utility equipment. It would seem appropriate, therefore, that before discussing pumps and compressors—two utility units driven by engines—we should at least comment briefly on the basic principles of engine operation. If you desire more information than is given here on various engine parts and their functions, study the Navy Training Course *Mechanic 3 and 2,* NavPers 10644–B.

DIESEL ENGINE OPERATION

Diesel engines change heat energy into mechanical energy. Heat is developed when a mixture of compressed fuel and air burns inside a cylinder. Expanding gases are formed. The gases exert a pressure on a PISTON which is connected to a CRANKSHAFT by means of a CONNECTING ROD. The straight-line movement of the piston is changed to a rotating movement of the crankshaft.

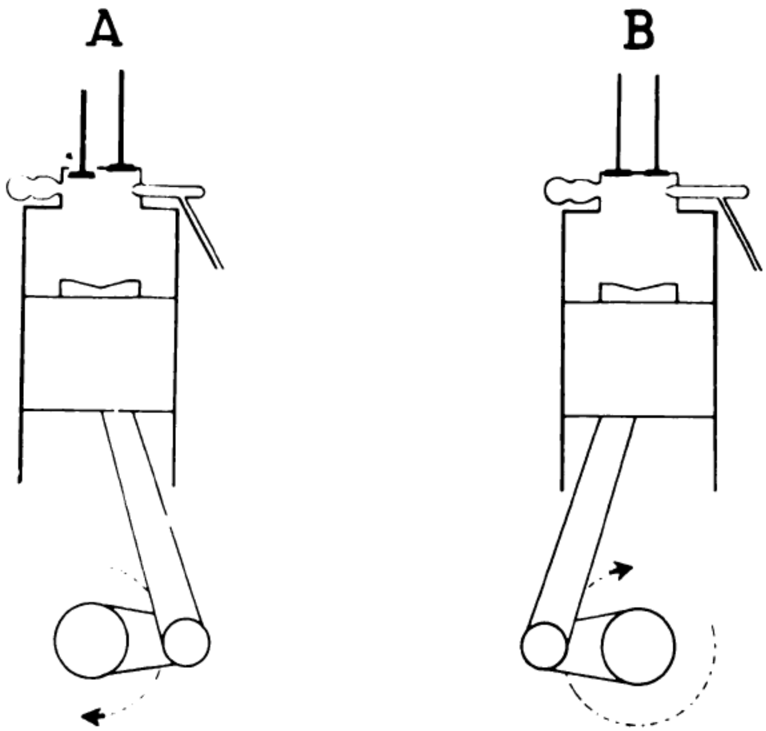
Four-Cycle Diesel

There are four-cycle and two-cycle diesel engines. In a FOUR-CYCLE engine, each cylinder imparts one power impulse to the shaft every fourth stroke of the piston, or every second revolution of the crankshaft. A two-cycle engine imparts one power impulse to the crankshaft per cylinder for every second stroke of the piston, or one power impulse per revolution of the crankshaft. First, we will discuss the principle of operation of the four-stroke cycle.

The following series of events take place in the four-stroke cycle engine: (1) inlet or intake stroke; (2) compression stroke; (3) expansion or power stroke; and (4) exhaust stroke. Four strokes of the piston, or two complete revolutions of the crankshaft, are necessary to complete the cycle.

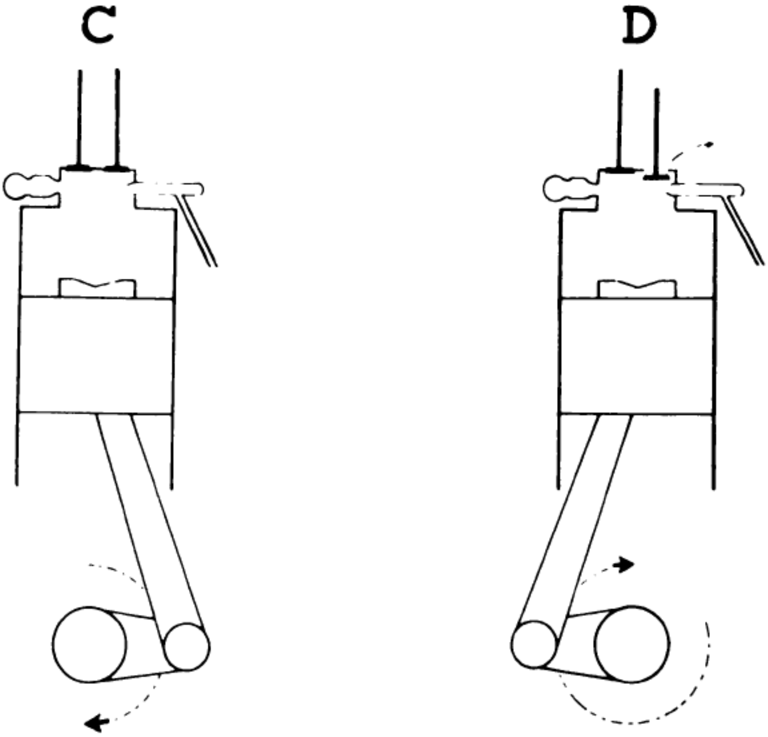
Figure 7–1 illustrates the four-stroke cycle in a diesel engine. In view A the crankshaft is forced to turn in the direction of the arrow and pulls the piston down. The inlet valve opens and a charge of air is admitted into the cylinder. This is called the INLET (or INTAKE) STROKE.

Now, note in view B that the piston is moving upward and the inlet valve is closed. As the piston moves upward it compresses the air into a smaller and smaller space. The decrease in volume causes an increase in pressure and a corresponding increase in temperature. Fuel oil is sprayed under high pressure into the combustion chamber just as the piston reaches the top of its stroke. The fuel ignites readily on coming into contact with the compressed air in the combustion chamber. This is called the COMPRESSION STROKE. In case the reason for ignition is



Inlet Stroke

Compression Stroke



Power Stroke

Exhaust Stroke

Figure 7–1.—Four-stroke cycle.

not clear, we might point out that all fuels have a certain temperature at which they will ignite. The temperature of the compressed air in the combustion chamber is well above that required for ignition of the fuel oil. Thus, the finely atomized spray of fuel oil ignites easily.

As indicated in view C, the burning fuel and air mixture expands rapidly and the piston is forced downward. Heat energy is changed to mechanical energy and the crankshaft is forced to rotate. Here you have the POWER STROKE.

In view D, the piston has completed the power stroke. As it starts upward the exhaust valve opens and the burned gases are pushed out of the cylinder. This is the EXHAUST STROKE, and completes the four-stroke cycle.

Of course, you usually have more than one cylinder in a diesel engine. The pistons are arranged on the crankshaft in a definite pattern. Thus, at any instant, each piston is in some phase of the four-stroke cycle. The result is a smooth delivery of power to the crankshaft.

Two-Stroke Cycle Diesel

The two-stroke cycle engine requires two strokes or one revolution of the crankshaft, while the four-stroke cycle requires two revolutions of the crankshaft to complete a cycle. The series of events that occur in a two-stroke cycle include (1) compression; (2) combustion and expansion; and (3) exhaust and scavenging.

For a run-down on how the two-stroke cycle operates, first note that part A, figure 7–2 illustrates a two-stroke cycle cylinder filled with a charge of air. The piston has started to move upward on the compression stroke and the exhaust valve is closed. The air in the cylinder is compressed and as the piston approaches the top of its stroke, fuel oil is injected into the combustion chamber. The fuel oil is under high pressure and forms a mixture that is easily ignited by the high temperature of the air in the cylinder.

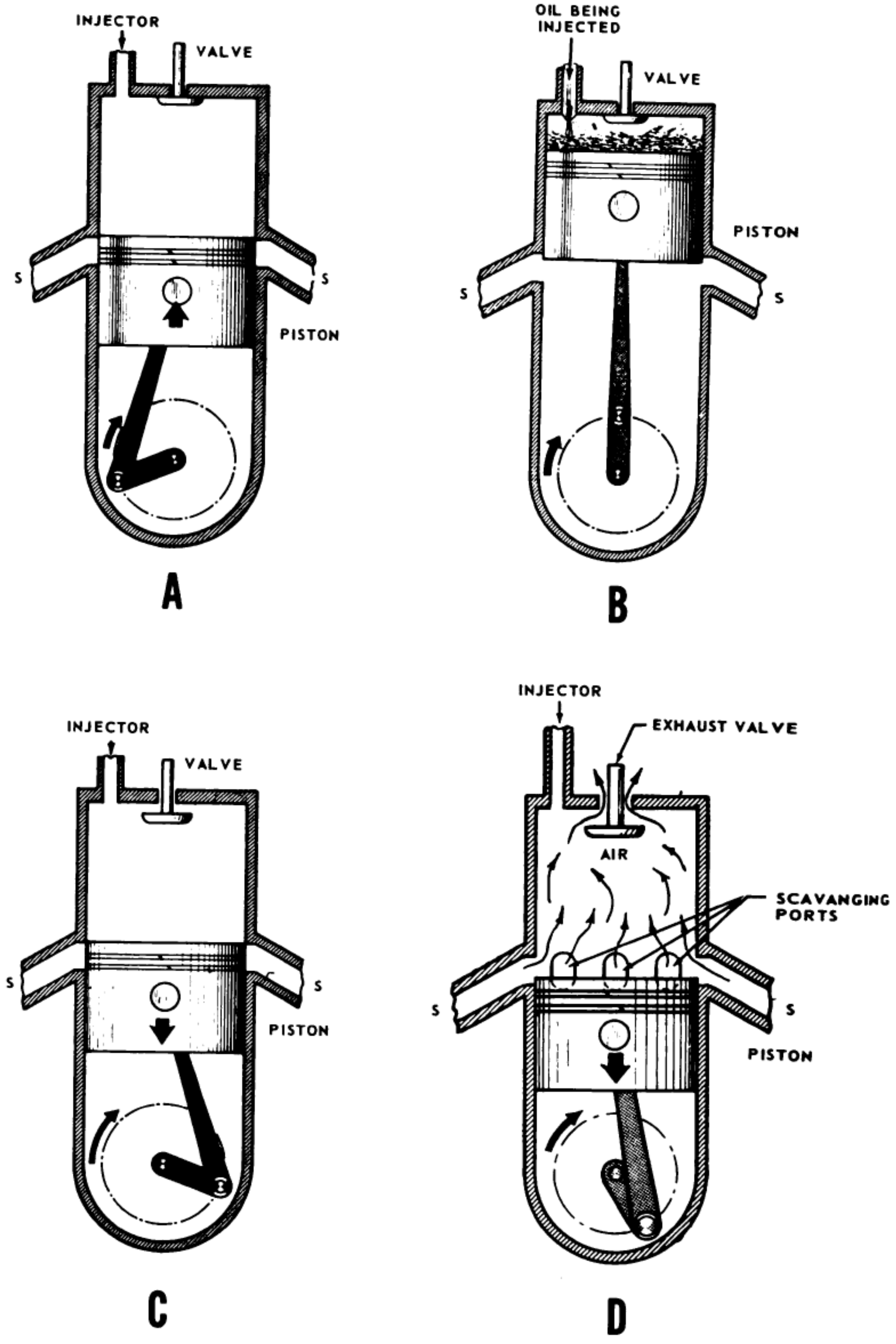


Figure 7–2.—Two-stroke cycle: A. Compression stroke, B. Power stroke, C. Near end of power stroke, D. Scavenging.

The fuel burns and the expanding hot gases force the piston down on the POWER STROKE (see part B, fig. 7–2). As the piston nears the end of the power stroke the exhaust valve opens and the gases are released to the atmosphere (see part C, fig. 7–2). The piston continues to move downward on the power stroke, uncovering scavenging air ports through which air under supercharged pressure is forced into the cylinder. (See part D, fig. 7–2.) This air is provided by a high-speed blower, which usually is engine-driven. The air forces out any remaining burned gases and supplies a fresh charge of air for the compression part of the next stroke. This operation, called SCAVENGING, is peculiar to the two-stroke cycle engine.

GASOLINE ENGINE OPERATION

Like the diesel engine, the gasoline engine changes heat energy into mechanical energy. Too, the physical construction of the gasoline engine is very much the same as that of the diesel. There are pistons, cylinders, valves, connecting rods, a crankshaft, and an engine block in each. There is also a cooling system to carry the heat away, a lubrication system to reduce the friction of moving parts, an air system to supply oxygen for combustion in the cylinders, and a fuel system to supply fuel.

Most gasoline engines operate on the four-stroke cycle. The difference between gasoline and diesel engine operation is (1) the method of introducing the fuel and air into the cylinders; and (2) the means by which the compressed fuel and air are ignited in the cylinders.

In a diesel engine the air is admitted to the cylinder on the intake stroke of the piston. The fuel oil is sprayed into the chamber AFTER the air has been compressed. In the gasoline engine the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. Figure 7–3 shows how it is done. The intake stroke of the piston sucks air through the air cleaner into the carburetor. In the carburetor the clean air is mixed with gasoline

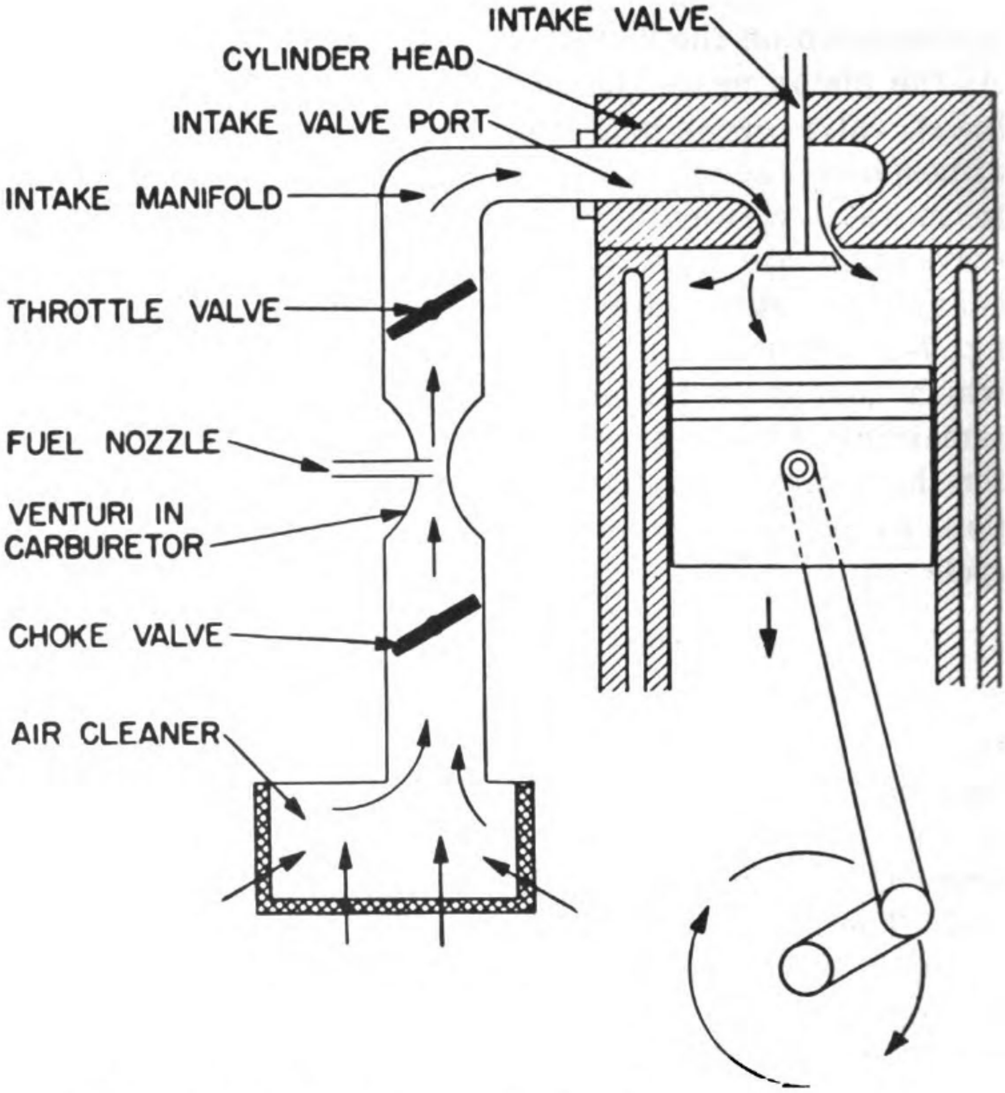


Figure 7–3.—Air and fuel are pre-mixed in a gasoline engine.

(vaporized) from the fuel tank. The air and gas mixture continue on to the intake manifold, which is connected to the cylinder head. An intake valve admits the air-gas mixture into the cylinder.

The diesel engine produces combustion by using the heat of compression. In the gasoline engine, an electric SPARK is produced by the spark plug to ignite the air-gas mixture. Ignition occurs as the piston completes its compression stroke. The ignited gases expand and the piston is pushed down in the power stroke. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber.

Just where does that ignition spark come from? In the small gasoline engines that are started by hand, the source of the spark is a MAGNETO. Large engines, which use a starting motor, have a BATTERY.

PUMPS

The pump has become the "heart" of many operations and many machines. The boiler, water purification and sewage systems, and construction jobs all have pumps in key spots. Much depends on the pump. It must function properly to do its job. If it fails, it ties up a lot of other equipment and may hold up the whole job.

The Navy uses many kinds of pumps. Two major types in use are reciprocating pumps and centrifugal pumps.

RECIPROCATING PUMPS are widely used in small installations. They work the same as the old hand-type well pump. On one stroke a suction valve opens and liquid is let into a chamber. On the second stroke the suction valve closes, the piston comes down and forces the liquid out through a discharge valve.

CENTRIFUGAL PUMPS work on a different principle. In this type of pump, centrifugal force is used to move the liquid through the pump and maintain the desired pressure. To illustrate the meaning of centrifugal force, imagine a man whirling a bucket of water rapidly around and around in a circle. The outward pull, or centrifugal force, developed by this whirling action will hold the water against the bottom of the bucket without spilling —even when the bucket is upside down.

In applying the principle of the whirling bucket to centrifugal pumps, suppose you have a number of bottomless buckets rotating about a center, as shown in part A, figure 7–4. The drum wall against which these buckets rotate forms a continuous bottom. As the buckets rotate, the water is held against this continuous bottom by centrifugal force.

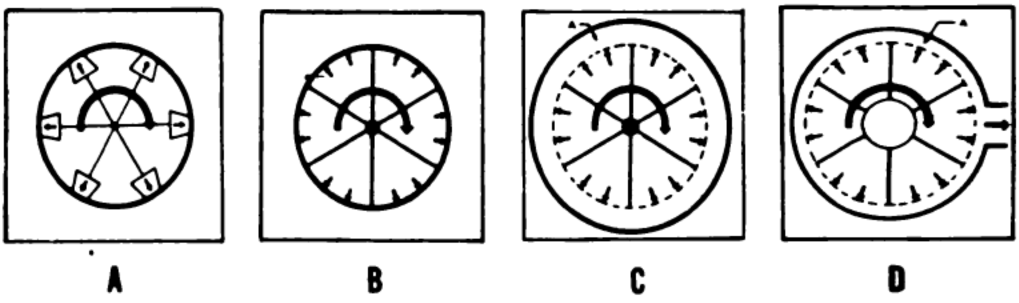


Figure 7–4.—Centrifugal force in a pump.

Now suppose that the buckets are arranged in pie-shape fashion as illustrated in part B, figure 7–4. When the buckets rotate they produce the same effect as a paddle wheel revolving in a drum-shaped container. Because of centrifugal force, there is a continuous liquid pressure all over the outer circumference of the container.

Let us suppose further that we increase the diameter of the container, as indicated in part C, figure 7–4. The purpose is to provide a space (*A*) for liquid between the ends of the paddles and the drum. The wedge-shaped buckets now have a liquid bottom, but the action remains the same as before. The rotation of the liquid in the buckets, owing to centrifugal force, pushes outward against the liquid bottom, thus producing pressure on the liquid in space *A*.

If an opening were made in the drum, this pressure would cause the liquid in space *A* to be discharged. Now let us go a step further and suppose that we provide (1) a central opening in the container, whereby the buckets will be continuously filled with liquid; and (2) a source of power to rotate the paddles. These additions make possible a continuous flow, as illustrated in part D, figure 7–4.

Many things can be written about pumps but very few statements apply to all pumps. There is one fundamental feature, however, in which all pumps are alike. They have two principal parts: (1) a WATER END, or PUMP END, in which force is applied on liquid to make it move through the pump and is then discharged; and (2) a POWER END where the energy of steam, electricity, or air is converted into power to actuate the piston or driver in the water end.

Reciprocating Pumps

The old-fashioned well pump led to the steam-operated reciprocating pump. The hand-operated lever was replaced and the piston in the pump barrel was attached to the piston rod of the steam engine. In this manner the up-and-down motion of the steam piston in the steam cylinder was transferred to the piston in the pump barrel. This particular type of pump is known as the single-acting pump or simplex pump (fig. 7–5).

After the simplex pump had been in use for some time, the next development was the duplex pump. The duplex pump is really two simplex pumps set up side by side.

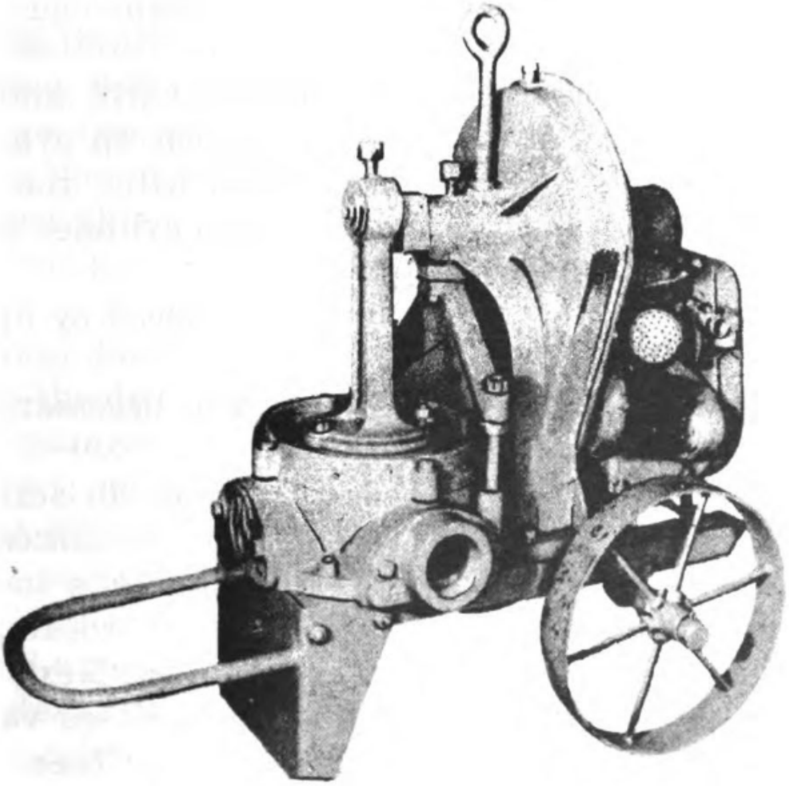


Figure 7–5.—Simplex reciprocating pump.

Thus, suction and delivery take place simultaneously on both the upstroke and the downstroke. This type of pump gives a more even flow of water.

The direct-acting steam-driven reciprocating pump is widely used because of its low initial cost, low maintenance, simple operation, and positive action.

OPERATION AND CARE OF A RECIPROCATING PUMP

It is your responsibility to operate and care for the pumps properly. After you have a head of steam, you start a reciprocating pump by following these steps:

1. Oil the pins of the steam valve operating gear and set up (screw down) on all grease cups.
2. Open the suction and discharge water end valves.
3. Open the top and bottom steam cylinder drains.
4. Open the cut-out (or root) valve in the exhaust and steam lines.
5. Open the exhaust valve of the steam end at the pump.
6. Crack (open a bit) the throttle valve and open slowly to admit steam and to warm up gradually.
7. Close the steam cylinder drains after the pump makes a few strokes and the steam cylinder is clear of water.
8. Bring the pump up to the proper speed by opening the throttle valve sufficiently.
9. Follow any additional steps found necessary with the particular design of pump.

Pump failure or the refusal of a pump to start will always cause inconvenience and, in many instances, may cause a serious situation. If your pump fails to start, there are a few things you can do to get it working.

First, close the steam and exhaust valves. Next, check the discharge and the exhaust lines for a closed valve or for a detached valve disk. If the pump has been out of service for some time, check the plunger of the steam piston to see if it is frozen or if there is excessive friction.

If you haven't found the source of trouble yet, remove the chest cover and examine the main valve to see if it has overridden or stuck. The steam valve must be wired and tagged to prevent opening while the main valve is being inspected. If the pump doesn't start now, it probably needs a complete overhaul of the steam end.

In operating the pump, keep it running at full stroke, but not at an excessive speed. The full stroke is stamped on the data plate of the pump. If 14″ x 10″ x 24″ is on the plate, the length of stroke is 24 inches. If necessary, you may have to adjust the cushioning valves to get the correct pump stroke. The other figures indicate that the pump has a 14-inch steam piston and a 10-inch water plunger.

A very small amount of cylinder oil is used on the steam ends of the rods, and all outside moving parts are lubricated with mineral oil. No oil is used in the steam or water cylinder. Remove the steam valves and valve gear frequently and clean them with kerosene. Before replacing, coat them thinly with mineral oil.

You may find a few common operating difficulties that cause you trouble. One of these is jerky operation on starting. This is usually due to a failure to take suction. To correct this, see that all stop or check valves in the suction line are open, and that the line is clear of obstructions.

You may find a pump "races" without appreciably increasing the discharge pressure. This racing is caused by a leaky plunger; a leaky, broken, or stuck valve in the water end; or by air being admitted to open or leaky valves in the suction line. Should a pump, which has been running properly, suddenly lose pressure on one stroke, look at once for a broken valve.

Should a pump stop when going very slowly, it may be due to steam passing worn piston rings. Check the rings and the cylinder for excessive clearance. If the pump stops, never jack it with the steam turned on—if you do, you may blow yourself into the sick bay.

Groaning in the water end is generally due to the packing being too tight. Groaning in the steam cylinder is usually due to steam getting behind the steam piston rings and forcing them out against the cylinder walls, to broken rings, or to the cylinder being out of alinement.

To stop and to secure a reciprocating pump, follow these steps:

1. Close the throttle valve.
2. Close the exhaust.
3. Open the top and bottom cylinder drains.
4. Close the water end suction valve.
5. Close the water end discharge valve.
6. Close the steam and exhaust cut-out valves.
7. After the steam cylinder is drained, close the steam cylinder drains.
8. In freezing climates, drain water from the entire system.

To keep reciprocating pumps in good operating condition, you must make a special effort to see that certain tests are conducted at regular intervals. Pumps standing idle should be jacked over by hand DAILY. The purpose of this test is to prevent rust, and to keep the piston from sticking to the cylinder wall.

It is important that all pumps be moved by steam or power WEEKLY. This is to make sure the pump is in good working condition and to free the pump piston rings of rust.

A QUARTERLY inspection is made to ascertain the condition of the pump. This includes inspecting the suction and discharge valves, valve stems, and springs, as well as the steam valve gear, for signs of wear. A check on the setting of the relief valves is also a part of this inspection.

An ANNUAL inspection is also made to ascertain the condition of internal parts of the pump. A major object of this inspection is to determine whether the sleeves, rings, or slide valves, as well as the bearings or cylinder walls, have become scored from excessive wear or clearances.

Before opening the water cylinder or valve chest of a pump handling water at a temperature in excess of 120° F, see that the suction and discharge valves are wired closed and tagged, and that the cylinder and valve chest are drained. When a pump is stuck or on dead center, remember to close the throttle valve and jack over by hand, with the steam turned off.

Centrifugal Pumps

In the past 30 years, centrifugal pumps have become widely used and in many cases have displaced the reciprocating pump. They are made in various forms, including single-suction volute, double-suction volute, open impeller, closed impeller, and a diffuser type. This type of pump is compact, is of simple construction, discharges at a uniform rate of flow and pressure, contains no valves or pistons, operates at a high speed, is driven by motors or steam turbines, and can handle dirty water.

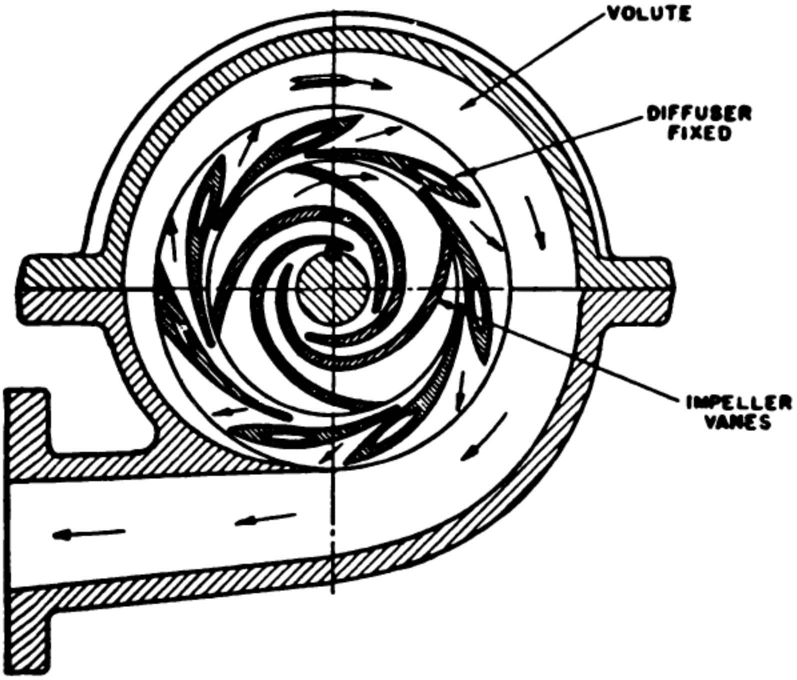


Figure 7–6.—Combined volute-turbine type of centrifugal pump.

The centrifugal pump consists essentially of a casing and an impeller (the rotating element) mounted on a shaft. The casing has suction, discharge, drain, and vent connections.

The liquid is guided from the suction chamber of the casing to the center or EYE of the impeller. The impeller gives a radial and rotary motion to the water, forcing it to the outer edge of the impeller. The water then flows through diffuser vanes and is discharged to the outer part of the casing, called the VOLUTE, and to the discharge connection on the casing. Figure 7–6 shows a type of centrifugal pump commonly used in the naval service.

OPERATION AND CARE OF A CENTRIFUGAL PUMP

To start a centrifugal pump, follow these steps:

1. Check the lubricating oil level in the sump tank or in the bearing housings. Fill the oil cups or reservoirs, if fitted.
2. Open the steam and exhaust casing drains of the turbine or the driving engine.
3. Open the valves on the pump to the gland water seals, where fitted. Slack up on the packing in the pump-stuffing boxes to permit a reasonable amount of leakage.
4. Open the steam and exhaust root valves.
5. Open the turbine on the engine exhaust valve.
6. Lift all relief and sentinel valves by hand.
7. Open the pump suction valve.
8. Open vent valves, or air cocks, at the top of the pump casing.
9. For main feed pumps, where fitted, open recirculating line valves and gland leak-off valve.
10. Start the motor.
11. After all the enclosed air has escaped, close the vent valves or air cocks on the pump casing.
12. For condensate pumps or other pumps vented back to a vacuum, open the valve in the vent connection.

13. When the pump is up to proper speed, open the discharge valve.
14. Check the lubrication system to see that all bearings are getting a proper supply of oil, and that the oil pressure is correct.
15. Check all gages to see that proper pressures are being developed.
16. Screw down the pump packing glands until the leakage is reduced to a mere trickle.

Proper operation and care is necessary to keep pumps going. Each manufacturer issues instructions for the operation and care of his pumps. Make it a point to always study and follow the instructions applicable to a paricular make of pump. They will help you to understand he equipment and how it works, and spell out the procedure by which you can obtain best results in operating he equipment.

To keep the centrifugal pump in good working order, t is essential, among other things, that you make an nspection of the packing at regular intervals. If an inpection shows the packing to be hard or charred, see hat it is renewed promptly. In making the replacement, lways use a soft packing material so that the shafts will ot be scored. The procedure for repacking will be disussed later in this chapter.

Particular care must be taken to see that the water iping to the seals or stuffing boxes is open and clear. Otherwise, there is a probability that the seal or the stuffing box packing will wear very rapidly, the shaft will e scored (gouged or grooved), and the air will be drawn n. Therefore, when the pump is running, a little water hould be allowed to trickle out of the stuffing box or seal.

The clearance between the impeller and the casing wearing rings should be maintained as shown on the manufacturer's plans.

Oil in the lubricating oil system should be renewed henever it becomes emulsified or foams excessively or sludge, dirt, or any foreign-matter is noticeable.

Before refilling a forced lubrication system with clean oil, flush out the system with hot flushing oil and drain it. Clean and wipe the sump tank and fill the system with clean lubricating oil. This oil should then be pumped through the system for a few minutes.

The oil reservoir should be checked frequently to see that it is free of water. If water is found in the oil, check particularly for leakage from the pump, turbine glands, and oil cooler. You should also clean the oil filters or strainers frequently.

If your pump doesn't deliver any or not enough water there are a few things you can check. See if the suction or discharge valve is closed or if the suction line is plugged with rags or dirt. If these are clear, check for air leaks in the suction lines.

The trouble may be due to the pump speed being too low or the suction lift or discharge head being too high. Another possibility is a mechanical defect in the pump such as a worn impeller, defective packing, or rotation in the wrong direction.

To stop and secure the pump, follow these steps:

1. Close the pump discharge valve.
2. Close the throttle valve or stop the engine (if steam driven).
3. Close the exhaust valve (if steam driven).
4. Close the vent valves.
5. For main feed pumps, where fitted, close recirculating and gland leak-off line valves.
6. Close valves on the pump to the gland water seals.
7. Close the pump suction valve.
8. Open the turbine or engine drains.
9. Close the steam and exhaust root valves.

To keep major repairs at a minimum and prolong the life of centrifugal pumps, they, too, should be tested at regular intervals. A pump that is standing idle should be turned by hand daily. Then, once each week the centrifugal pump should be given a test run by power and the operation of the discharge check valves observed carefully.

A quarterly inspection should also be made. It consists of checking bearing clearances, examining and setting up on all foundation bolts and dowel pins, and checking the internal water-lubricated bearings and shafts for wear or scoring.

Once a year the pump should be opened and given a thorough inspection and cleaning. This calls for examining the diffusers, impeller, shafts, and shaft sleeves. In addition, see that you check carefully the clearance of the bushing, impeller, and wearing rings—renewing if necessary.

Other Types of Pumps

In addition to the pumps discussed so far in this chapter, you may use a number of other kinds in your work. One of these is known as the POSITIVE DISPLACEMENT ROTARY PUMP. To a large extent, the positive displacement pump has supplanted the reciprocating pump for pumping viscous liquids, and where the pumping problem involves suction lift or priming. It can be used, also, for pumping liquids such as water and gasoline.

The simple gear-type of pump shown in figure 7–7 consists, essentially, of a casing in which two intermeshing gear-type rotors are mounted. As the gears rotate, the liquid is trapped in the spaces between the gear teeth and the pump casing and is carried around with the gears to the discharge side of the pump. As the teeth come in mesh, the liquid is squeezed out of these spaces and is prevented from leaking back to the intake side. Pressure is built up and the liquid is forced out of the pump and into the discharge line.

Essentially a self-priming pump, the positive displacement pump is capable of producing a high vacuum—as much as 20 to 25 inches of mercury. A point to note is

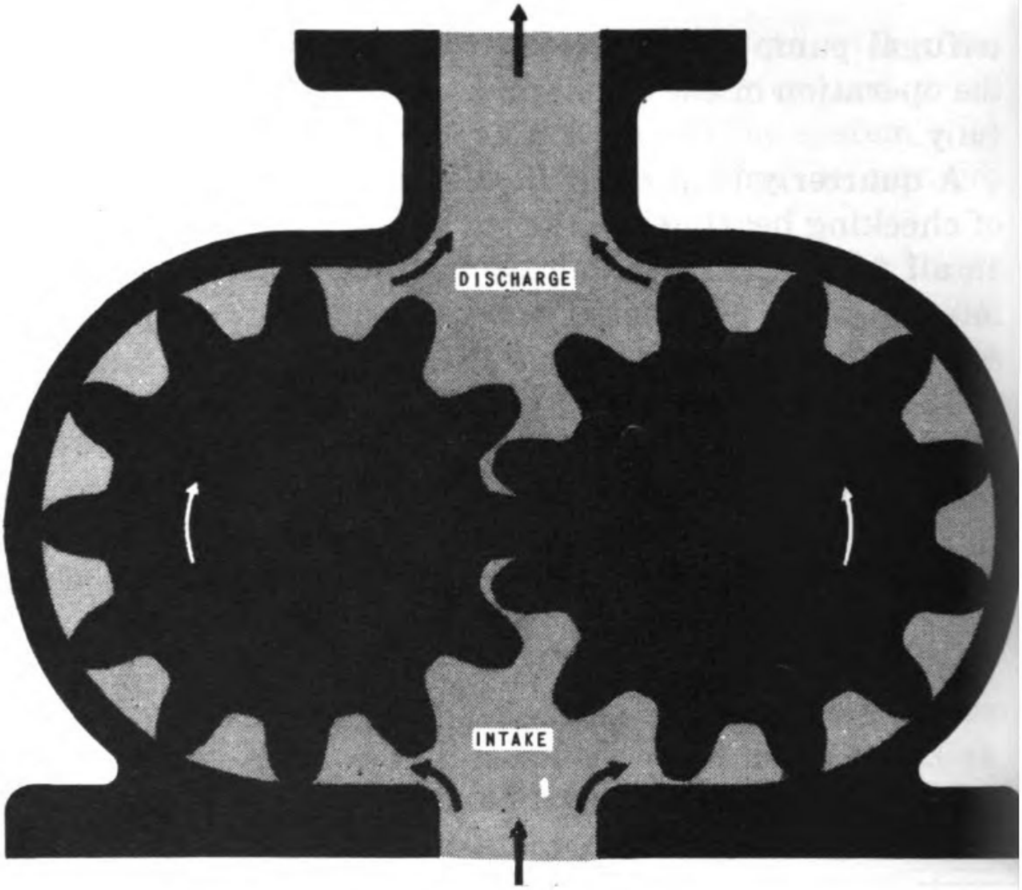


Figure 7–7.—Operating principle of a simple gear pump.

that while the gears and housing of this pump are sturdily constructed, they are likely to crack or warp under heavy stress or strain.

It has been found through investigation that a positive displacement rotary pump will pull a vacuum or lift a liquid as well as, if not better than, a reciprocating pump in average condition of repair. It has also been disclosed through experience that, with any positive displacement pump, the volumetric efficiency will decline rapidly if the pump is required to operate on a vacuum or suction lift exceeding about 20 inches of mercury. The most efficient vacuum to operate this pump is 15 inches of mercury.

DIAPHRAGM PUMPS are especially designed for pumping mud, slime, sand, silt, ooze, and any heavy waste or liquid containing debris such as stones, sticks, or rags. You will probably use them for such specific duties as dewatering trenches where sewer lines or water mains are to be laid, so that joints can be poured. Diaphragm pumps are capable of pumping from a cupful to a barrelful of water per minute without a change in speed.

Two types of diaphragm pump are the mud hog (closed-discharge) and the water hog (open-discharge). The MUD HOG is suitable for jobs that require pumping heavy thick liquids, and where the liquid must be discharged at a distance away from the pump. It is fitted with discharge hose connections and tight-seated ball valves and chambers. The valve chambers of the mud hog are designed to prevent clogging by sticks, stones, rope, rags, and so forth.

The WATER HOG is used for pumping lighter, thinner, less viscous liquids than the mud hog. Both types, however, handle liquids containing sand, gravel, mud, and so on. The discharge from the water hog is open to give free flow and increased capacity. With this type, the liquid is discharged at the pump. The discharge hose may be connected, but if so, efficiency will be reduced considerably. The water hog uses a nonsticking, flapper-type of suction and discharge valves.

Power for the diaphragm pump is usually supplied by means of a gasoline engine. The pump works on the lift and force principle. It has a suction lift of 23 to 25 feet. The up and down motion is attained by means of a connecting rod between a crankshaft and walking beam, pivoted on a fulcrum post. On each side of the walking beam is a pump rod which connects to the center of a diaphragm in the pump barrel.

On the upstroke, the diaphragm is forced up and a vacuum is created. This vacuum lifts the suction valve off its seat and pulls down on the discharge valve, causing it to seat. On the downstroke, this action is reversed. Therefore, liquid is taken in on the upstroke and discharged on the downstroke.

A JET, or EJECTOR, pump is sometimes used to pump ground water. This type has a centrifugal single-impeller

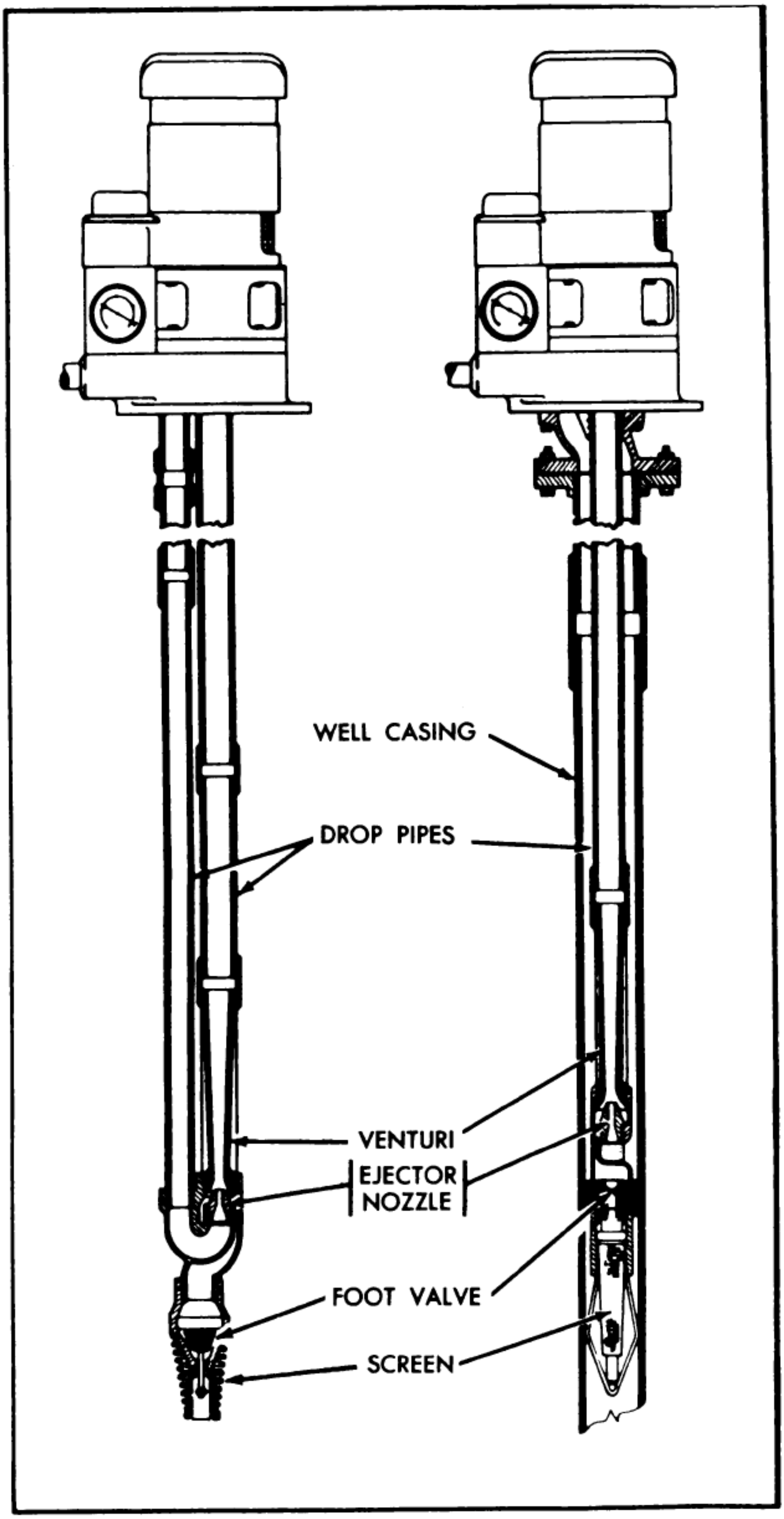


Figure 7–8.—Jet pump installed over well.

pump above ground and a stationary ejector assembly in the well. Use of the jet pump is confined ordinarily to small wells of limited depth. It can be installed either away from or directly over a well, since there are no moving parts in the well. Figure 7–8 illustrates its installation over a well.

In operation, the jet pump rotates at high speed, throwing water out of the volute or housing through the discharge line. Part of this water is passed back to the ejector assembly through a small pressure line. It goes first to the pressure chamber, then is forced through the nozzle and into the narrow throat of the tube. On leaving the tube it has a high velocity, which creates a reduced pressure. This reduction in pressure causes water to enter from the well and rise in the pump suction pipe. The pump suction then lifts the water, and the cycle is completed.

To achieve best results, have the ejector assembly about 10 feet below water level. Always install a suction pipe with a foot valve at the bottom to make the unit self-priming after it is started.

Two other types of pump are: the hi-lift and the air-lift. The HI-LIFT pump is based on the principle of SQUEEZING water instead of pushing or whirling it. This pump is self-priming, develops a high pressure, is simple and compact, and has a uniform liquid flow.

The AIR-LIFT pump is used in pumping water or oil from wells. It consists of a discharge pipe and a smaller air pipe, both partially submerged in a well. The air pipe introduces compressed air into the bottom of the discharge pipe. The mixture of liquid and air formed by this method rises to the surface. This principle is illustrated in figure 7–9.

Packing

In early days, little attention was given to packing materials and packing spaces for pumps. If the pump was giving trouble a handful of packing material, usually hemp rope or leather, was added.

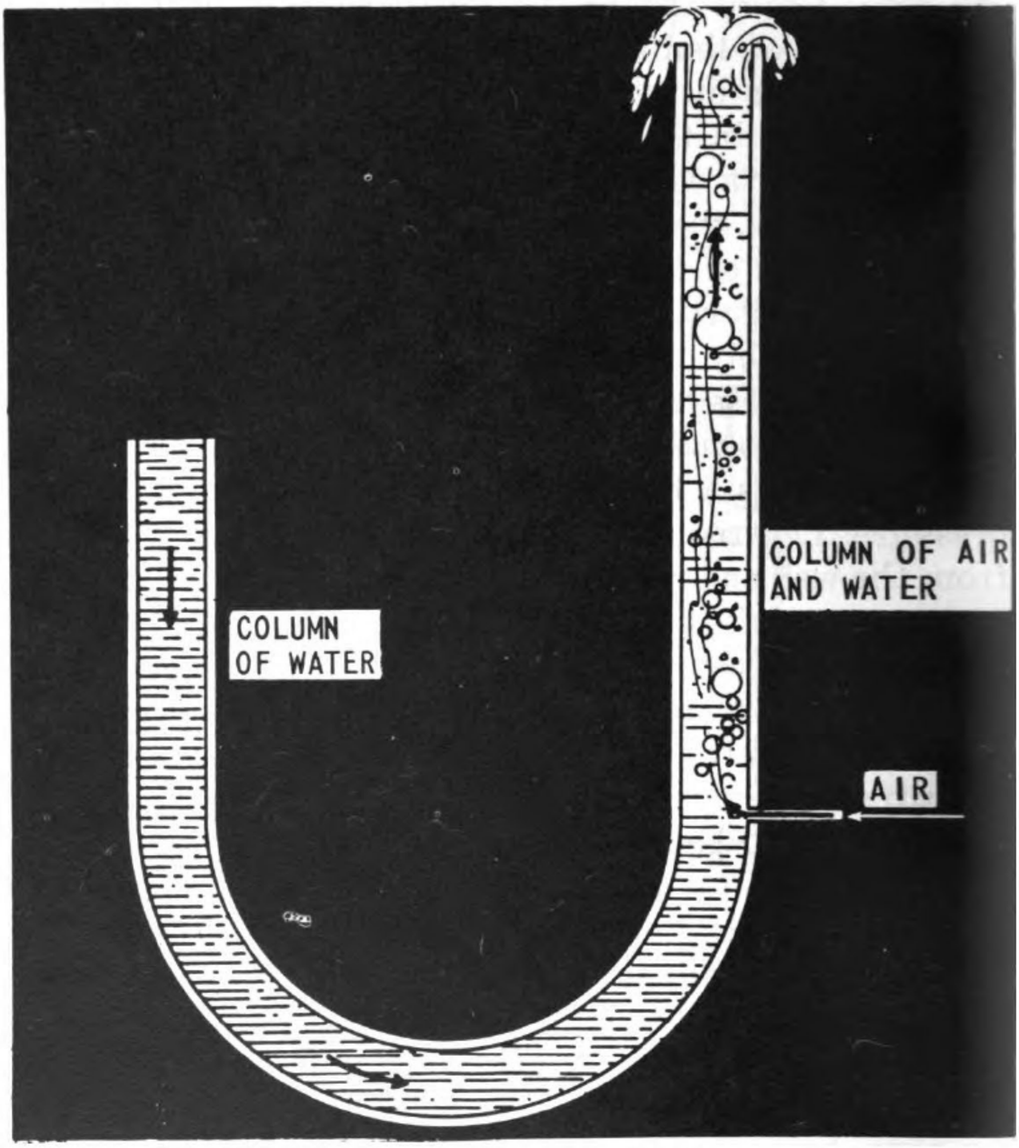


Figure 7–9.—Air-lift pump principle.

Now much more attention is paid to packing, and at one time there were over 60 different types of packing approved for naval service use. These types have been standardized and assigned Navy symbol numbers. These symbols and the materials they represent are listed in Bureau of Ships Standard, B–153.

Packing is used to seal machinery joints against leakage. Fixed joints, such as flanges, do not offer as much

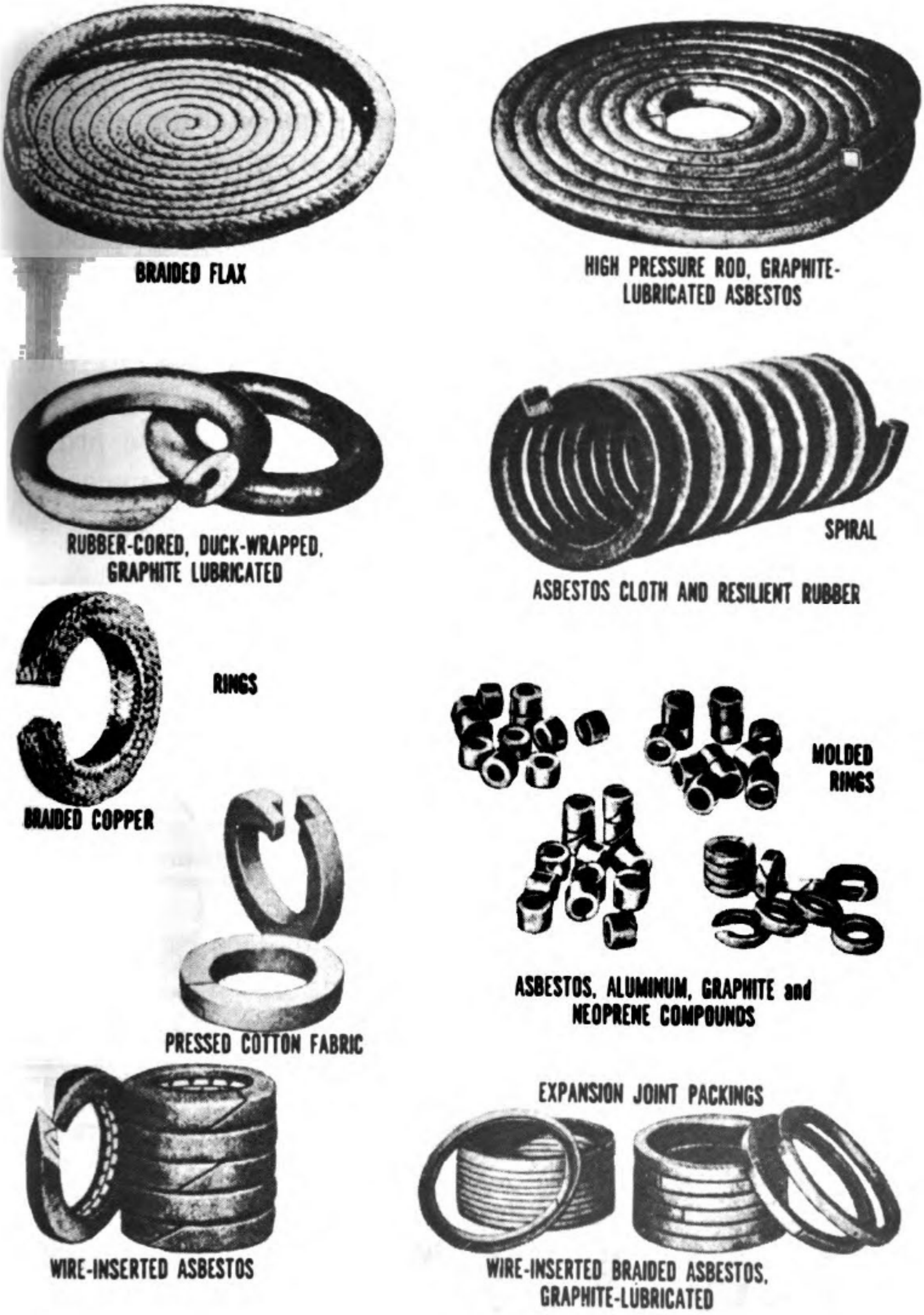

BRAIDED FLAX
HIGH PRESSURE ROD, GRAPHITE-LUBRICATED ASBESTOS
RUBBER-CORED, DUCK-WRAPPED, GRAPHITE LUBRICATED
SPIRAL
ASBESTOS CLOTH AND RESILIENT RUBBER
RINGS
BRAIDED COPPER
MOLDED RINGS
PRESSED COTTON FABRIC
ASBESTOS, ALUMINUM, GRAPHITE and NEOPRENE COMPOUNDS
EXPANSION JOINT PACKINGS
WIRE-INSERTED ASBESTOS
WIRE-INSERTED BRAIDED ASBESTOS, GRAPHITE-LUBRICATED

Figure 7–10.—Types of packing.

difficulty in packing as do moving joints, such as pistons, shafts, or valve stems. It is necessary to seal the moving joints without causing excessive friction, undue wear of the moving part, and early failure of the packing.

Today, packing is made from asbestos, rubber, metals, and plastics as well as other materials. Wire-inserted square-braided and plastic-nonmetallic-asbestos packing have been developed for high pressure use. Packing is made in different forms as shown in figure 7–10.

Packing is inserted in stuffing boxes (fig. 7–11), which are cavities located around valve stems, rotating shafts, or reciprocating pump rods. These cavities are stuffed with a packing material, which is compressed as necessary and held in place by flanged, bolted, or threaded gland bushings.

In normal operations, the packing on a shaft should not run excessively hot. The packing, therefore, must be

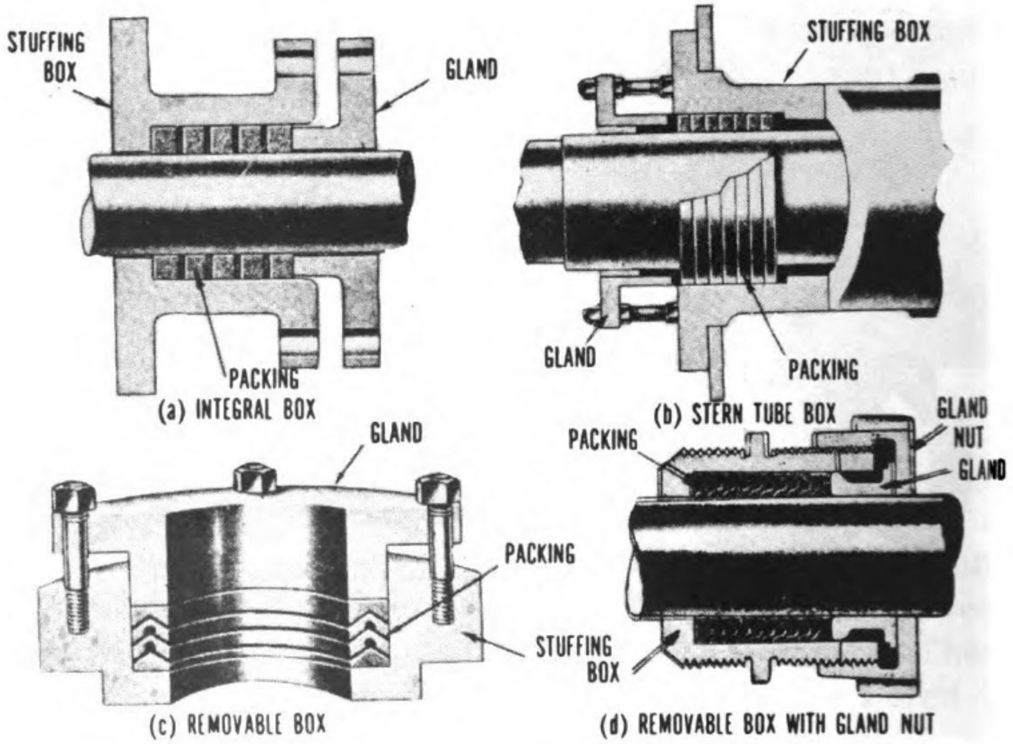


Figure 7–11.—Stuffing boxes.

lubricated. All packings have some lubricant in them. In pumps that handle liquids that do not contain abrasives, the liquid itself may act as a lubricant. These pumps may have a water seal and a lantern gland (fig. 7–12). A slight drip of water comes out of the gland.

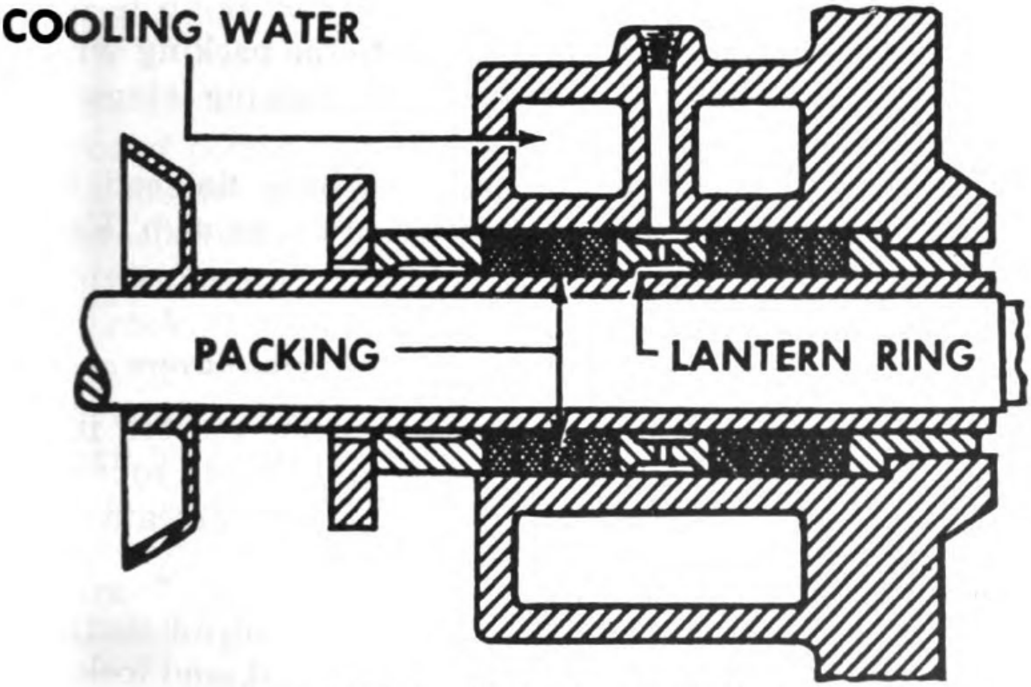


Figure 7–12.—Liquid-cooled pump packing.

If the packing of a pump is giving trouble, check the pump for misalinement, vibration, bent shafts, or scored sleeves. These conditions may be the cause of the trouble. You will find it necessary to replace pump packing from time to time. The manufacturer's instructions will assist you in this job.

If you are using tucks or flax or other hydraulic-rod packing, soak it in water for at least 12 hours before you cut and fit it. This is to allow for swelling. If, in an emergency, you use this packing while it is dry, allow clearance for the swelling that will take place when it becomes water-soaked.

In replacing metallic packing, be sure that you have the set designed for your type of stuffing box. Fit the packing carefully and see that the rod is true and that all parts are clean.

When replacing woven or braided packing, remove all old packing with a removal hook. Be sure to clean the inside of the stuffing box or gland and the surface of the stem. The ends of the packing should be cut square. After inserting the packing into the stuffing box, tamp it into place with a packing tamper. Lubricate the packing while you insert it. Stagger each joint in packing rings to prevent leakage.

Tighten all bolts equally after you have finished the packing. A uniform, fingertight pressure is enough. Keep the bolts well oiled and clean.

Safety Precautions for Pumps and Prime Movers

In working with pumps and their prime movers it is essential that you exercise care to avoid injury to yourself and others. Here are a few important safety precautions which you should keep uppermost in mind.

1. Before beginning work, make sure that all suction and discharge valves are wired, tagged, and locked.
2. If steam operated, throttle and exhaust valves should be wired, tagged, and locked.
3. If electrically operated, the switch should be pulled, wired, tagged, locked, and the fuses removed.
4. If operated by an internal combustion engine, the ignition switch should be in OFF position and tagged; also, if clutch is provided, it should be disengaged and locked in place.
5. Clothing should be worn properly. For instance, avoid loose ends or flaps in the breeze. Keep sleeves rolled down and buttoned.
6. Do not carry in your pockets any loose gear which may fall out into moving machinery or machinery under repair.

7. Observe all standard safety practices applicable to working around moving equipment and to fuel handling.
8. When internal combustion engines are being used, see that exhaust fumes are vented outside the structure.

AIR COMPRESSOR

The air compressor provides a flexible, lightweight source of power. It puts air under pressure in a confined space, and from there it is forced through discharge valves to attached work tools. That is how the rock drill, for example, obtains power necessary to cut its way through solid rock. On construction jobs it is not unusual to see several different tools being operated by power from the same compressor.

Portable compressors are gasoline-engine-driven, diesel-engine-driven, and electric-motor-driven. In naval service, diesel-engine-driven compressors are used a great deal. Figure 7–13 shows you a portable diesel-engine compressor designed for heavy-duty work. Bear in mind that ability to operate the engine is important to operation of the air compressor. We might add that knowing how to operate other types of utility equipment and the prime mover used to drive them is just as important as with the air compressor.

Starting Compressor and Engine

To keep the air compressor and its engine in efficient operating condition, the operator must be familiar with the proper operating procedure. Among various makes of compressors and engines you may find some variation in operating procedure. The procedure given below should apply, basically, to any gasoline- or diesel-driven compressor.

Before actually starting the compressor and engine a few items should be checked to make sure the equipment

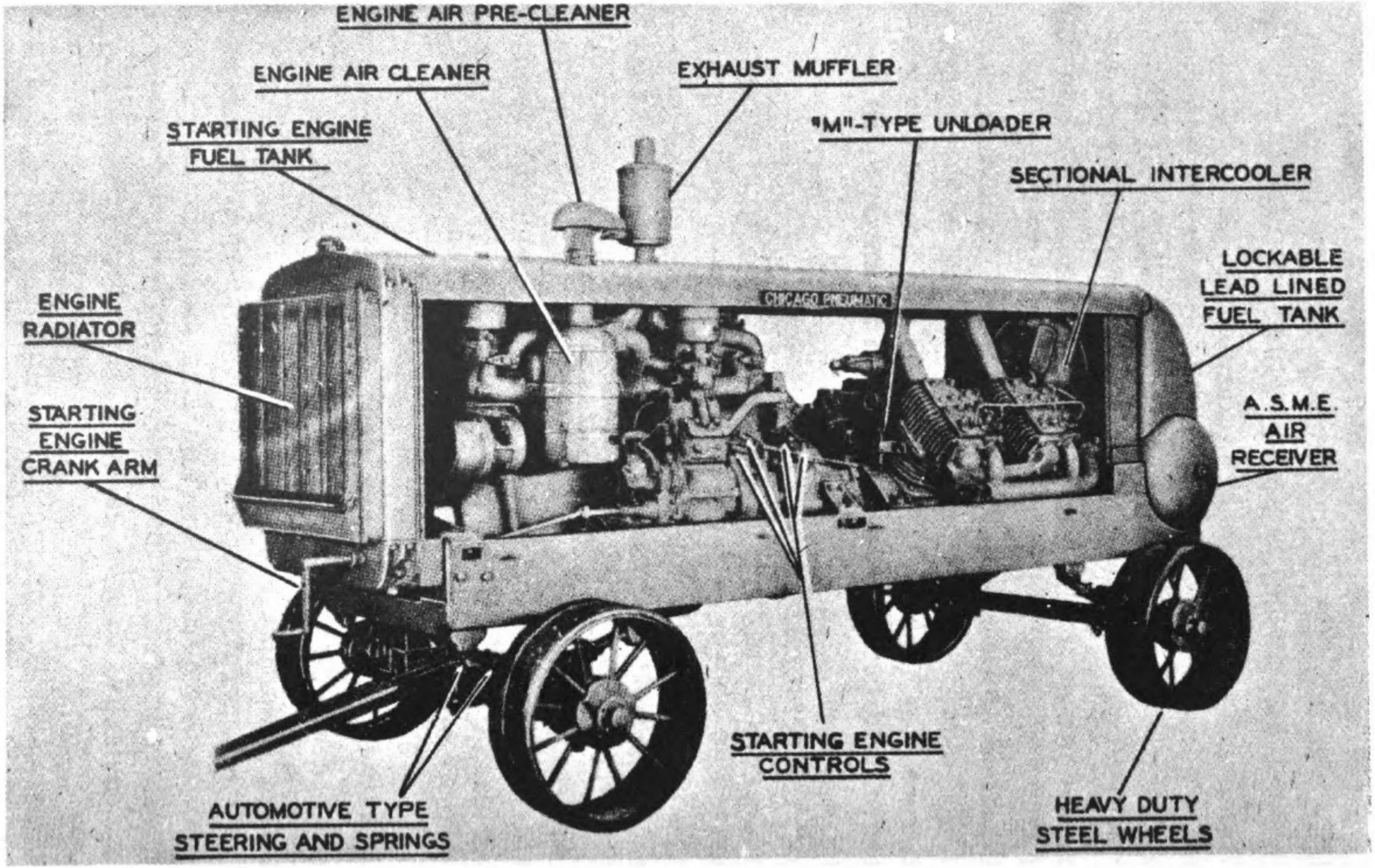


Figure 7–13.—Portable air compressor.

is in operating order. First, check the compressor for loose parts and to see if it is clean. Then check to make sure that oil is at the proper level in the engine, filter, and compressor crankcase. Parts that may need lubricating include the fan bearings, magneto, water pump, clutch, and starting motor. Of course, you will need to check on the supply of fuel. Make sure the fuel has no dirt or water in it. Next, open the fuel line shut-off valves. Don't forget to check the water level in the radiator.

Next, disengage your clutch and turn the compressor over by hand, with the ignition off, to ensure that working parts are free and ready for starting. Then open the air cock drain on the air receiver tank, and check your fan belts for tightness. Now you are ready to pull out the choke, turn on the ignition switch, and get started. If the unit is fitted with a starter, simply press the starter button and push in the choke half way.

Suppose the engine is a small gasoline-driven engine with no starter provided. In that case, close the carburetor choke and crank the unit by hand, using a rope. To crank with a rope, insert the knot at the end of the starting rope in the notch in the starting sheave and wind the rope on the sheave in a clockwise direction. Now give a brisk pull on the rope to turn the crankshaft over. If the engine fails to start on the first try, repeat the operation. If the choke accidentally snaps open during cranking, close it again. If you see fuel start to drip from the carburetor, open the choke. As a safeguard, see that no one stands close to you or to the engine. An accident could easily occur should the starting rope whip around during the cranking process.

After getting started, push in your choke (if it has been pulled out part way) as the engine warms up, and check the oil pressure gage. Allow about 10 full minutes for the engine to warm up. To keep the engine from stalling, engage the compressor clutch slowly. If it does stall, allow a few more minutes for warming up. Next, check the compressor oil pressure. Open the drain cock on the air tank to let the air blow out, and then close it. Now check the air pressure gage, and this completes the starting procedure.

After Starting

After getting started, check on the engine and compressor oil pressure gages, also the air pressure gage. Lift the relief valve by hand, regulating and adjusting when necessary. Next, check to make sure the pilot valve is operating properly, then proceed to adjust the automatic valves and ascertain that all of them are operating. With that done, operate the compressor and engine as desired. Make sure you avoid operating at excessive speed.

Securing

When time comes to secure the compressor, here is what you must do:

SHUT off the valve on the air receiver.

ALLOW the unit to operate unloaded for several minutes.

TURN off the ignition switch.

OPEN the drain cock on the bottom of the air receiver. Reason: to remove moisture, air, and oil.

LEAVE the clutch engaged until time comes to start the compressor again.

IF you are in a cold climate, SEE that the antifreeze solution is strong enough to keep the radiator from freezing.

Servicing

Lubrication and cleanliness are important factors to consider in connection with servicing and maintaining the compressor. Study the manufacturer's instructions on the specific compressor concerned. If the manufacturer's manual is not immediately available, here are a few pointers to keep in mind:

Lubricate the compressor regularly. Use only the proper grade of oil, and avoid the application of too much oil. Lubricate the fan and clutch bearings individually. In cold weather, a lighter oil may be necessary.

Always keep the machine clean and free of gasoline or kerosene fumes. Most air compressor explosions are due o the presence of oil or kerosene vapor or dirt or dust in he air used. Be sure the machine has clean, dry air! Clean the air filter as often as local conditions require.

Accidents have been caused by disconnecting parts of he compressor system while still under pressure. To avoid this, the entire system must be blown out and drained, and the pressure gages left open.

Don't play around with the air compressor. It's dangerous to blow compressed air on any person or to put your hands into the moving machinery.

TWO RELIABLES

Some people think that only the big pieces of equipment are important. They look for the steam shovel and the bulldozer at a construction job.

Most people overlook the part played by the pump and the compressor. These two are like the linemen of a football team plugging away and making it possible for others to score the touchdowns while they get no recognition or glory.

The pump and compressor do big jobs and save a lot of time. If you doubt it, try bailing out a cellar with a hand bucket or try breaking through rock with a ball-peen hammer.

The man who operates a pump or compressor, MUST do his job right. Proper operation and care of his machine will help everyone on the job. Careless or inefficient operation will handicap everyone. It's a job that MUST be done the right way.

QUIZ

1. What is an internal combustion engine?
2. What are the four strokes that take place in a 4-stroke cycle engine?
3. How is combustion produced in the diesel engine?
4. Do most gasoline engines operate on the four-stroke cycle or the two-stroke cycle?
5. In the gasoline engine, how is the air-gas mixture ignited?
6. What is the two-stroke principle on which the reciprocating pump works?
7. What are the two principal parts that all pumps have?
8. The old-fashioned well pump led to the development of what type of pump?
9. In starting the reciprocating pump why should the throttle valve be opened slowly?
10. What is the first thing to do if the steam-operated pump fails to start?
11. What valves are adjusted to give a pump a full stroke?
12. What should you use to clean steam valves and the valve gear of a pump?
13. What is the name of the rotating element in a centrifugal pump?
14. What is the name of the outer part of the casing of a centrifugal pump?
15. After starting a centrifugal pump, when do you open the discharge valve?
16. What type of pump operates on the principle of squeezing water instead of pushing or whirling it?
17. How is the packing in stuffing boxes held in place?
18. If the packing of a pump is giving trouble, what defects should you check for?
19. In securing the air compressor, what is the purpose of opening the drain cock on the bottom of the air receiver?
20. Why is it important that the air used by the compressor be free of oil or kerosene vapor, as well as dust or dirt?

CHAPTER 8

WATER TREATMENT PROCESSES

A ready supply of safe, pure water is essential to the existence of man. Water is so necessary to the functioning of the human body that one could survive a longer time without food than without water. We use water not only for drinking but for many other purposes as well; for instance, cooking, washing, bathing, swimming pools, sewage disposal, laundries, washing vehicles, and so forth.

Water is necessary to the survival of plants and animals, as well as human beings. It is also needed to operate various types of equipment, including the automobile. Let us note, too, that water plays a gigantic role in today's big-time industries. A striking example is the use of water as a means to turn the wheels of hydroelectric plants that supply electricity to light cities and to furnish power for industries. Actually, industries in the United States use billions of gallons of fresh water daily, in addition to the stream flow used to produce power.

IMPURITIES

In our discussion of water, let us not overlook the fact that water can be a source of danger and destruction. That is because of the many impurities which are often found in water. Actually, you can expect to find impurities in practically all water. Some of these impurities do not amount to much, while others are extremely dangerous to health. Impurities in water can be broken down into two major categories: suspended impurities and dissolved impurities.

SUSPENDED IMPURITIES include organisms, as well as organic and inorganic materials which usually make the water turbid or muddy-looking. Water-borne diseases caused by dangerous organisms include typhoid, paratyphoid, cholera, and dysentery.

DISSOLVED IMPURITIES are organic or inorganic materials or chemicals which may cause an unpleasant taste, color, or odor in the water.

TREATMENT AND PURIFICATION

Various methods of treatment and purification are used to eliminate impurities in water and, in so far as possible, make it pleasant to drink. You should be familiar with some of the principal methods in common use because water treatment and purification is a major responsibility of the Utilities Man. To keep you aware of the seriousness of this responsibility, bear in mind that safe, pure water is essential to naval operations everywhere. How well you carry out your duties involving the treatment and purification of water is a matter that will concern the health and welfare of all personnel using the water.

Some of the major processes used in various combinations in the treatment and purification of water are: flocculation, sedimentation, filtration, disinfection, aeration, and distillation. These processes will be discussed separately in subsections which follow. You may find a number of other processes in use, so consider our discussion here as an introduction to the subject only.

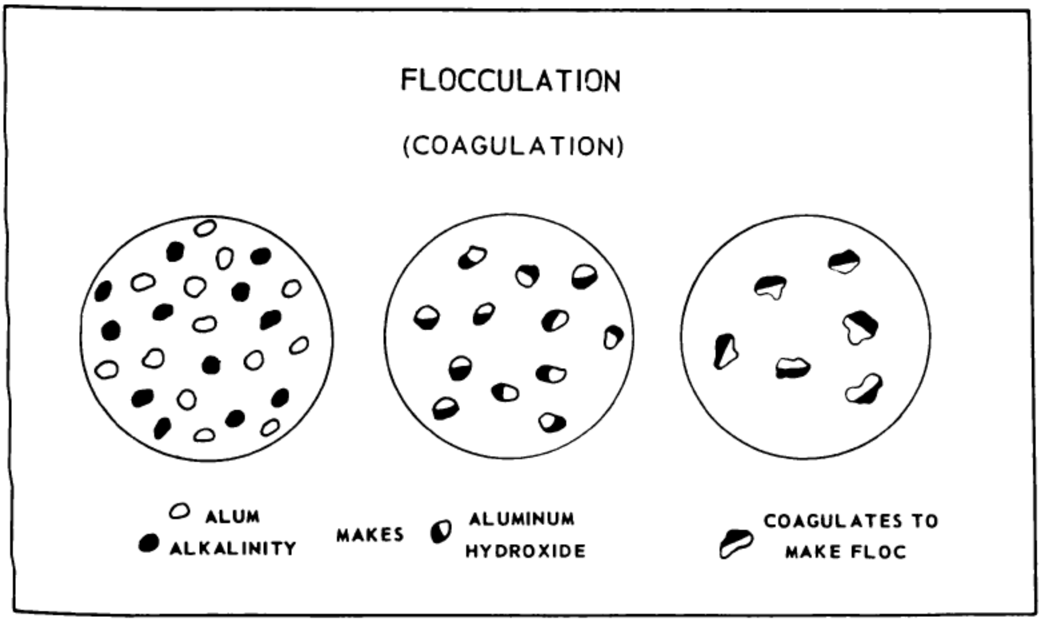
We will discuss various types of portable water treatment units in chapter 9, then take up distillation units in chapter 10. You will be briefed on what to expect in the way of routine duties in a water purification plant in chapter 11. In view of the total coverage given the subject of water treatment in this one textbook, you can readily see that it is a mighty important phase of the over-all water supply picture. Now let us take a look at the different processes named in the preceding paragraph.

Flocculation

FLOCCULATION (or COAGULATION) is the process of forming FLOC or precipitate by the addition of floc-forming chemicals. The floc traps suspended matter and some of the bacteria present in the water. This action results in an increase in the size and weight of suspended matter and causes it to settle quickly.

A common floc-forming chemical is ammonium alum. If sufficient natural alkali is not present in the water to form a good floc, additional alkali (soda ash) must be added. Before proceeding, study figure 8–1 carefully for a clear-cut idea of how flocculation works.

When water is to be treated by the process of flocculation, it is important that a *p*H reading be taken at the original source of the water. This is necessary to deter-



Courtesy of Engineer School, Fort Belvoir, Va.

Figure 8–1.—Process of flocculation.

mine the intensity of alkalinity or acidity of the water. The acidity or alkalinity of the raw water will influence treatment processes. Measuring the intensity or degree of the acidity or alkalinity of the water is known as determining the *p*H value.

Take a close look at the *p*H measuring scale shown in figure 8–2. Note that the scale contains 14 divisions. The first seven divisions indicate acid conditions, with a *p*H of 0 being the maximum acidity. At midpoint, *p*H 7, the water is neutral, with the acid and alkaline substances in it balancing each other. This does not mean that the water is pure, however. The last 7 divisions indicate an alkaline condition, with a *p*H of 14 representing the maximum alkalinity.

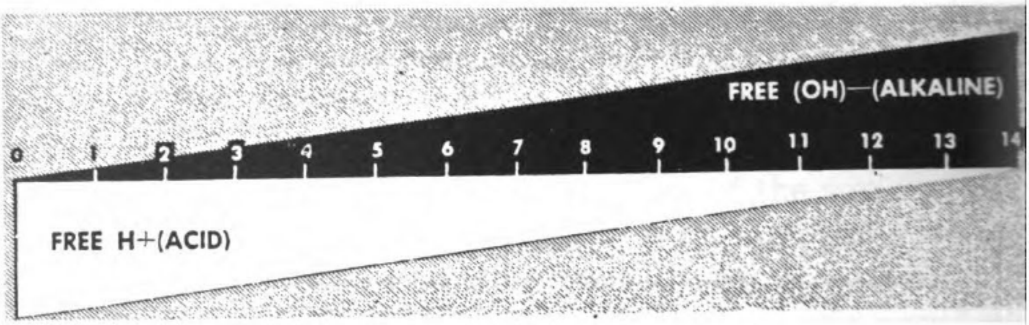


Figure 8–2.—pH scale.

In addition to a *p*H reading, a *p*H determination test should also be made at the original source of water to be treated by flocculation. The purpose of a *p*H determination test is to find at what *p*H floc will best form. When this *p*H has been found, it is said to be the optimum *p*H. The procedure for making the *p*H determination test will be discussed later in this chapter, in the section on "Tests."

Mechanical devices such as mixers, agitators, and baffles are an advantage in flocculation since they keep the precipitate suspended in the water long enough to produce a heavy floc. To do a good job in mixing floc-forming chemicals with the water, you will need to develop skill in the techniques of (1) flash mixing, and (2) slow mixing.

In FLASH MIXING the water is passed through a chamber where revolving paddle arms, with stationary vanes between, accomplish the mixing. Some mixing equipment is so designed that considerable turbulence is set up inside the chamber. This, of course, is beneficial to the mixing process. Make sure you are careful, though, to see that agitation is not violent enough to break up the floc. In brief, the object of good agitation is to achieve even mixing throughout the chamber. The flash-mixing stage generally takes from 1 to 2 minutes, with a velocity of more than 5 fps (feet per second).

To aid in settling, flash mixing usually is followed by SLOW MIXING, or gentle agitation. This allows the precipitate being formed to collect into heavy floc particles, which settle to the bottom.

Slow mixing requires a 20- to 30-minute detention period, with a 0.5- to 1.5-fps velocity. Both the degree of agitation and length of detention will depend largely on your experience with the water being treated.

Bear in mind that slow mixing calls for precision control if best results are to be achieved. To this end, the speed of the agitator for slow mixing must be variable. Endeavor to obtain the most complete mixing possible.

Sedimentation

If you were to dip up a glassful of water from a moving stream and proceeded promptly to observe its contents, you would probably discover a goodly number of solid particles being held in suspension in the liquid. At first these particles are more or less equally dispersed; but as the water becomes still, they start settling to the bottom of the glass. The settling of solids in this manner is caused by the natural action of gravity. In the water-treatment field, clearing water by this natural settling process is known as SEDIMENTATION.

In conventional treatment, settling immediately follows flocculation. The ideal detention period for settling after slow mixing is about 1½ hours.

Filtration

Not all of the suspended matter is removed by sedimentation. Therefore, another process known as SAND FILTRATION is used. Sand filtration is the passing of water through beds of porous material. The beds are usually layers of fine sand overlying layers of coarser sand and gravel.

In an emergency, you may have to fix up a substitute filter. You may use a woolen blanket, cotton bed sheet, or other fibrous material for this purpose. These substitutes will not remove bacteria or do the complete job of the regular filter. But they will remove some impurities such as leaves, twigs and larger particles.

Usually, rapid sand filters are used. These filters are of two types, GRAVITY and PRESSURE. In the mobile and portable water purification units, the pressure-type filters are installed. These filters use coagulation and sedimentation as preliminaries in helping produce clear water. They can be operated to remove some of the harmful bacteria and to produce filtered water of generally high quality.

The rapid sand filters have an arrangement to reverse the flow of water through them. This backwashing quickly removes accumulated solids and must be done at frequent intervals. Filtered water should always be used for backwashing.

Another type of filter is the DIATOMITE. Because of its light weight this filter is widely used at advanced bases. It removes suspended matter from water by passing it through a porous mat of diatomaceous silica. Diatomaceous silica is the skeletal remains of tiny algae, called diatoms, found in marine deposits which have been lifted above sea level.

The diatomite (also called diatomaceous earth or filter-aid) is supported by wound wire in a porous plastic or rubber cylinder. This supporting base or "septum" is porous enough to permit maximum flow. It is also fine enough to support the filter cake that coats the septum.

Since failure of pressure will cause the mat to drop off the septum and permit raw water to pass through the permeable septum, the diatomaceous earth filter is not considered sufficiently safe for water supply facilities at shore activities, except at advanced bases, where the water is always given a high dose of chlorine, and an operator is always present.

Diatomaceous earth filters provide a satisfactory means of purifying water in swimming pools. However, the use of these filters in preference to pressure sand filters must be justified by the over-all economies to be realized in first cost and plant operation.

Diatomite filters are backwashed by reversing the flow of water and drawing filtered water from the storage tank through the filter. This is done whenever necessary to keep the filter output from falling off. The turbidity of the water will largely determine the frequency of backwash.

Disinfection

The term DISINFECTION refers to the process of killing or removing any harmful organisms that cause disease. A good point to remember is that: A PROPERLY DISINFECTED WATER IS SAFE.

No water, except from SAFE underground sources, should be supplied to naval personnel for domestic use without some kind of disinfection. Generally speaking, disinfection means CHLORINATION. Liquid chlorine or powdered chlorine compound is the killing agent. Exceptions, such as iodine tablets or boiling, should be permitted only in an emergency by small units at advanced bases.

Water supplied from wells or relatively pure lakes or streams may require no treatment other than chlorination. With many less pure supplies, chlorination may provide a number of special benefits in addition to disinfection. For instance, chlorination can improve coagulation, control biological decomposition, prevent algae growth, control growths in pipelines, diminish tastes and odors, and aid filter operation.

Calcium hypochlorite illustrates the use of chlorine in the form of a powdered compound. High-test hypochlorite, about 70 percent available chlorine, is commonly used at advanced bases and small activities. That is understandable since the hypochlorinators which are used to feed hypochlorite are simpler and cheaper than chlorination equipment.

In addition to calcium hypochlorite, other hypochlorite compounds such as bleach (24 to 35 percent available chlorine) may be used, if approved by the medical officer. Calcium hypochlorite, though, is the most effective of the powdered compounds.

As a liquid, chlorine is available in metal containers ranging in capacity from 100 to 2,000 pounds. Pressure keeps the tanked chemical as a liquid; it is fed as a gas by means of a chlorinator. Bear in mind that chlorine gas is poisonous. Safety precautions should be carefully observed in handling chlorine gas!

SAFETY

Only reliable and trained personnel should be permitted to handle chlorine. When you are considered as knowing your job well enough to be granted the responsibility of handling chlorine, here are some safety precautions you should follow carefully:

—Avoid dropping or bumping chlorine cylinders.

—Store cylinders in moderate temperature, away from steam lines or fire.

—Never connect a full cylinder to a header with other cylinders until temperature and pressure of both are approximately the same.

—Keep protective valve caps on cylinders, except when using, and replace when cylinder is empty.
—Keep valves closed at all times, except for actual delivery of chlorine.
—Close valve as soon as cylinder is empty.
—Do not use oil on chlorine valves.
—Do not refill containers.
—Never put any other gas in chlorine cylinders. Do not mix gases or let moisture or air into cylinders. Never use cylinders as rollers or supports.
—Never apply a flame or blowtorch to a cylinder.
—Do not ship a defective or leaking cylinder until it is empty; it is illegal. Mark plainly, DEFECTIVE.
—Get help from your chief petty officer, if necessary, to handle chlorine emergencies.

USE OF CHLORINE

As part of the working knowledge necessary to efficient use of chlorine as a disinfectant, the UT should familiarize himself with the meaning of these terms: chlorine demand, chlorine residual, and chlorine dosage.

CHLORINE DEMAND means the minimum amount of chlorine required to kill all the harmful organisms in the water.

CHLORINE RESIDUAL is the amount of chlorine remaining in the water after at least a 20-minute storage period, after the demand of all chlorine-consuming agents has been satisfied. The chlorine content is expressed in ppm (parts per million). Military field requirements are at least 1 ppm chlorine residual. Make it a point to remember that 1 ppm would indicate that you have 8.34 pounds of available chlorine to a million gallons of water. To emphasize the importance of an adequate chlorine residual, let us point out that if you have NO CHLORINE LEFT IN THE WATER the water IS NOT safe and more chlorine must be added and another chlorine residual test made.

CHLORINE DOSAGE indicates the sum of chlorine demand plus chlorine residual. In other words, it is the minimum amount of chlorine that is required not only to kill the harmful bacteria in the water, but also to leave a residual.

In producing potable water, a chlorine-residual test should be made frequently, if you want to be sure of always having an adequate residual. The purpose of this test is to determine the chlorine content of the water. The chlorine-residual test will be discussed a little later in this chapter, in the section on "Tests."

Tastes and Odors

No one likes to drink water that has an unpleasant taste or odor. It is possible to treat the water so that the odor will not be noticed and the water will be palatable or pleasing to drink.

Aeration is one way by which most tastes and odors can be removed. It is the process of exposing water to the air, and thereby allowing odor-producing materials to escape as vapors.

Aeration is accomplished by spraying the water into the air, passing air under pressure into the water, or by allowing the water to flow over cascades, or through beds of coke.

Another way of removing most of the unpleasant tastes or odors is by passing the water through beds of activated carbon. This is a relatively pure, finely powdered form of carbon which does an excellent absorption job. It may be added before, during, or after coagulation, or directly on the filters. Dry activated carbon should never be mixed with chlorine because of the danger of explosion.

Distillation

DISTILLATION refers to the process of purifying water by boiling and condensing the vapor produced. It is commonly used in the purification of sea water. It also may be used for water which contains excessive amounts of dissolved solids. In addition, distillation may be used in the purification of contaminated or polluted water.

In distillation units, heat boils water in an evaporator and changes the water into steam. The steam passes through a condenser, with distilled water being produced as a result. Figure 8–3 illustrates a distillation unit in its simplest form.

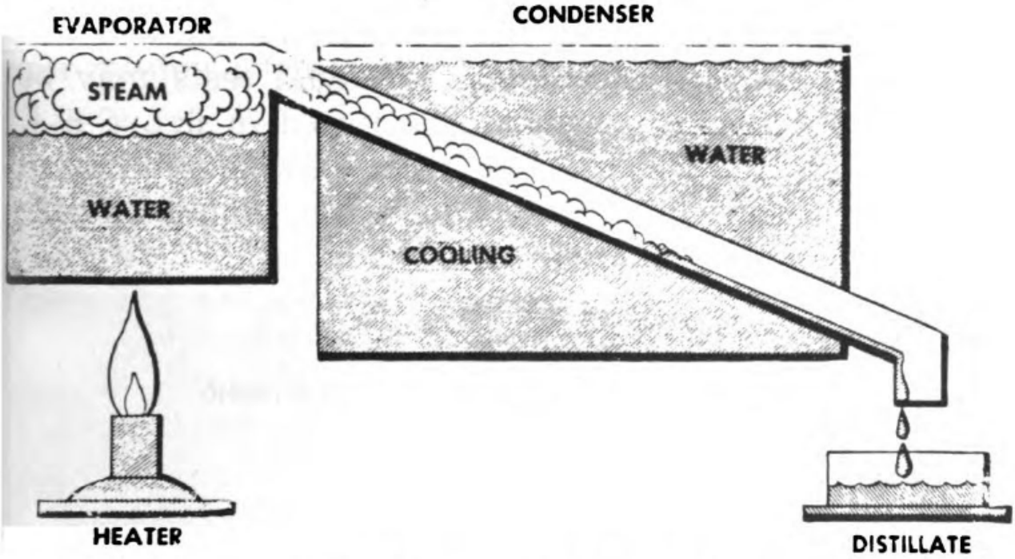


Figure 8–3.—Distillation unit in its simplest form.

Do not overlook the importance of chlorinating distilled water. One reason for chlorination is the possibility of the water becoming contaminated by containers prior to its use. It is possible, of course, for distilled water to pick up dangerous organisms during dispensing. Maintaining a chlorine residual in distilled water provides a safeguard against this possibility.

TESTS

During World War II it was found that taste, odor, and appearance of water were rather unimportant in actual combat, where a large supply of water not only was needed but was difficult to obtain. The important thing was that the water be free of disease germs. Troops engaged in warfare are as dependent on an adequate supply of safe water as they are on guns and ammunition. With lives at stake, water—a necessity of life—must be SAFE!

There are several tests that help ensure the safety of water, and also aid in processing it. Two such tests are the *p*H determination test and the chlorine-residual test. As pointed out earlier, the purpose of the chlorine-residual test is to determine the chlorine content of the water. The *p*H determination test, as explained in the section on flocculation, is made to find the *p*H at which floc will best form. Both the *p*H and chlorine-residual tests may be made with the color comparator pictured in figure 8–4.

In the chlorine-residual test, you add orthotolidine to a sample of water in a tube. This water should be over

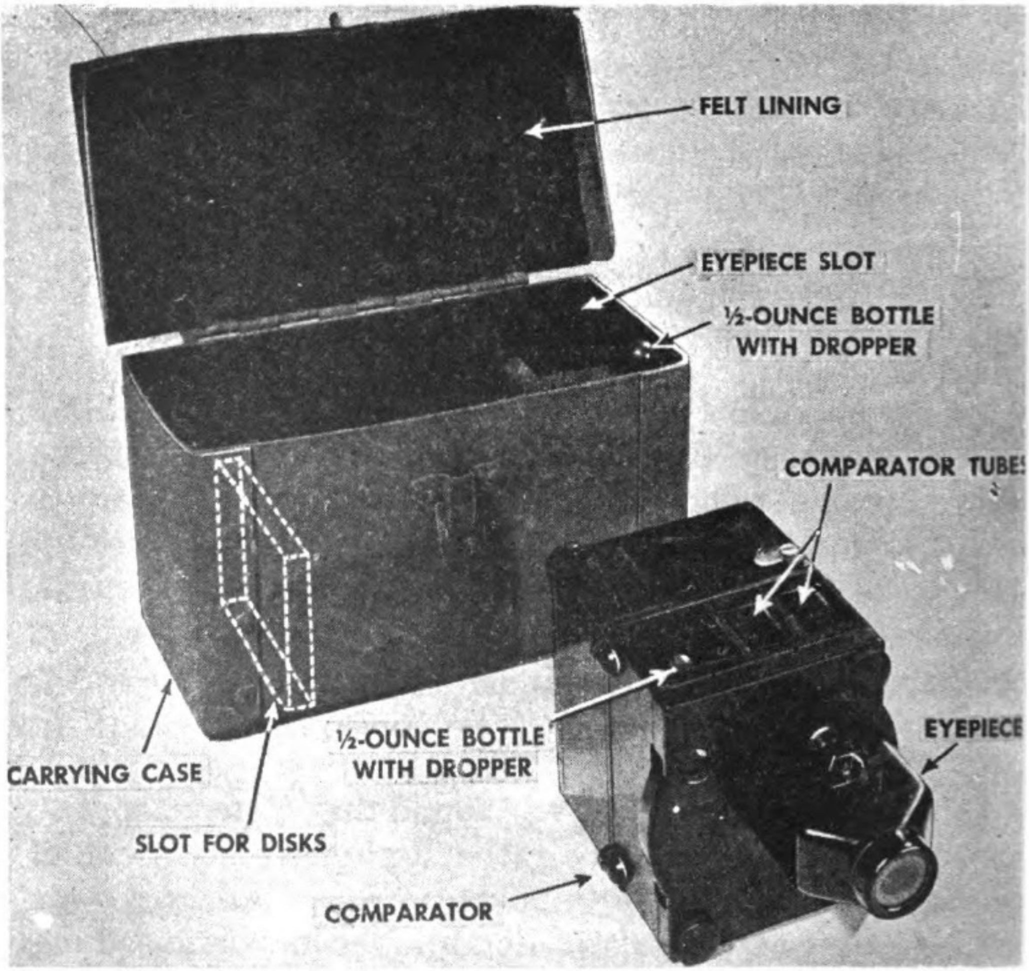


Figure 8–4.—pH and chlorine-residual comparator.

50° F in temperature. The solution is placed in the comparator behind the viewing hole. Another tube with a sample of the water is placed behind the colored glass disk. The comparator uses a standard color disk to match the sample of water. Five minutes is allowed for color development before the matching operation.

You rotate the disk until the tube containing the indicator and the colored glass in the disk are matched. Then the chlorine-residual value may be read directly in parts per million (ppm). The maximum reading on the disk is 2 ppm.

The comparator also contains three standard color disks for use in color matching to determine the *p*H value.

In the *p*H test there are three indicator solutions:

1. Bromcreosol purple green
2. Bromthymol blue
3. Aqua purple.

Usually the bromthymol blue solution is added first. The same procedure is followed as in the chlorine-residual test, except that no 5-minute waiting period is needed. If there is no match, the other solutions are used.

The condition for greatest precipitation or "optimum *p*H" generally occurs somewhere between *p*H values of 4.0 and 7.6, depending upon the type of water being purified. Colored waters containing only a small amount of dissolved solids generally coagulate best between *p*H values of 4.0 and 6.6, while very turbid waters coagulate best between 6.0 and 7.6.

Another test with which you should be familiar is known as the FLOC TEST. It consists of merely taking a sample of the water being treated by the process of flocculation and observing it for proper floc formation. If floc formation is not right, you must then make a *p*H test to find out what is wrong.

In observing the sample for proper floc formation, here are several things it will help you to know:

—Floc should form in 2 to 5 minutes.

—Floc should form and settle in 5 to 10 minutes.

—Floc should be from 1/8″ to 1/4″ in diameter.

—If floc forms but does not settle, you have too much alum in the water; if floc settles too rapidly, you have too much soda-ash or not enough alum.

—To LOWER the *p*H during the process of flocculation, increase the amount of feed from the alum feed pot.

—To RAISE the *p*H, increase the amount of feed from the soda-ash feed pot.

QUIZ

1. What are dissolved impurities?
2. Which method of treatment uses floc-forming chemicals to form floc or precipitate in the water?
3. What is the purpose of a *p*H reading?
4. Why is a *p*H determination test made at the original source of water to be treated by flocculation?
5. What is the ideal detention period for settling after slow mixing?
6. Name two types of rapid sand filters used in filtration.
7. How are diatomite filters backwashed?
8. To what does the term "disinfection" refer?
9. In chlorination, what requirement should be met before using bleach (24 to 35 percent available chlorine) instead of calcium hypochlorite?

0. What is meant by the term "chlorine demand"?

1. What is the meaning of "chlorine dosage"?

2. What is the purpose of the chlorine-residual test?

3. What does 1 ppm chlorine residual mean?

4. Name two ways of removing unpleasant tastes and odors in water.

5. What precaution would you take to prevent distilled water from becoming contaminated?

6. What is the name of the color agent (indicator) used in making the chlorine-residual test?

7. To lower the *p*H during the process of flocculation, would you increase the amount of feed from the alum feed pot or from the soda-ash feed pot?

8. What is the size of a good floc?

CHAPTER 9

PORTABLE WATER TREATMENT UNITS

There is usually a specialized piece of equipment for almost every job.

At advanced bases you will find portable water treatment equipment which can be shifted from place to place. This equipment usually consists of comparatively small units. If you need more water than one small unit will produce, use two or more units.

EMERGENCY MEASURES

You may find yourself far away from a regular supply of water and water purification or distillation equipment. You may have to use emergency measures to provide your own safe water.

Various chemicals may be used for emergency treatment of water. A common type used by the Seabees is iodine tablets.

Iodine tablets for water treatment are packed in bottles of 50 tablets, each tablet of 120 milligrams. Usually, one tablet is inserted in a standard issue canteen. This applies, however, only for clear water. If the water is dirty or discolored, use two tablets. It is extremely important that directions on the bottle be followed carefully. Iodine tablets are highly effective in the destruction of harmful organisms in water, but they are dangerous when improperly used.

Another method of emergency purification is by means of a calcium hypochlorite ampule. One ampule is dissolved in a full canteen of water. This solution is then used to purify the water in other canteens (one canteen capful of the solution for each canteen). Allow 30 minutes after mixing before using the water. Do not make the mistake of allowing the ORIGINAL solution to be drunk.

Remember that iodine tablets and calcium hypochlorite ampules are intended only for EMERGENCIES. As soon as a reliable source of water is available, their use must be discontinued immediately.

LYSTER BAG

A Lyster bag (fig. 9–1) is primarily a dispensing unit for purified or distilled water. These bags are sturdy, watertight, and readily collapsible for packing. Water is withdrawn through small faucets at the bottom. Each bag supplies enough water for 99 men.

When no other purification equipment is available, a Lyster bag may be used to disinfect raw water. Normally, two chemical kits for purification purposes are supplied with each Lyster bag. A kit contains these items: 100 tubes, each containing ½ gram of calcium hypochlorite; two chlorination test kits, each with 50 orthotolidine tablets, and a plastic testing tube; and 100 sodium sulfide tablets.

The water is treated for about 10 minutes with an ampule and is then tested for chlorine content by means of an orthotolidine tablet. The testing tube usually has a yellow band. When an orthotolidine tablet is dropped in the treated water, the resulting color should be the same, or slightly darker than the ring. Lighter colors indicate insufficient chlorination, while an orange color shows overchlorination. In the case of insufficient chlorination, add another ampule and re-test in 10 minutes. For overchlorination, add more water and re-test.

If you believe that the raw water may contain harmful

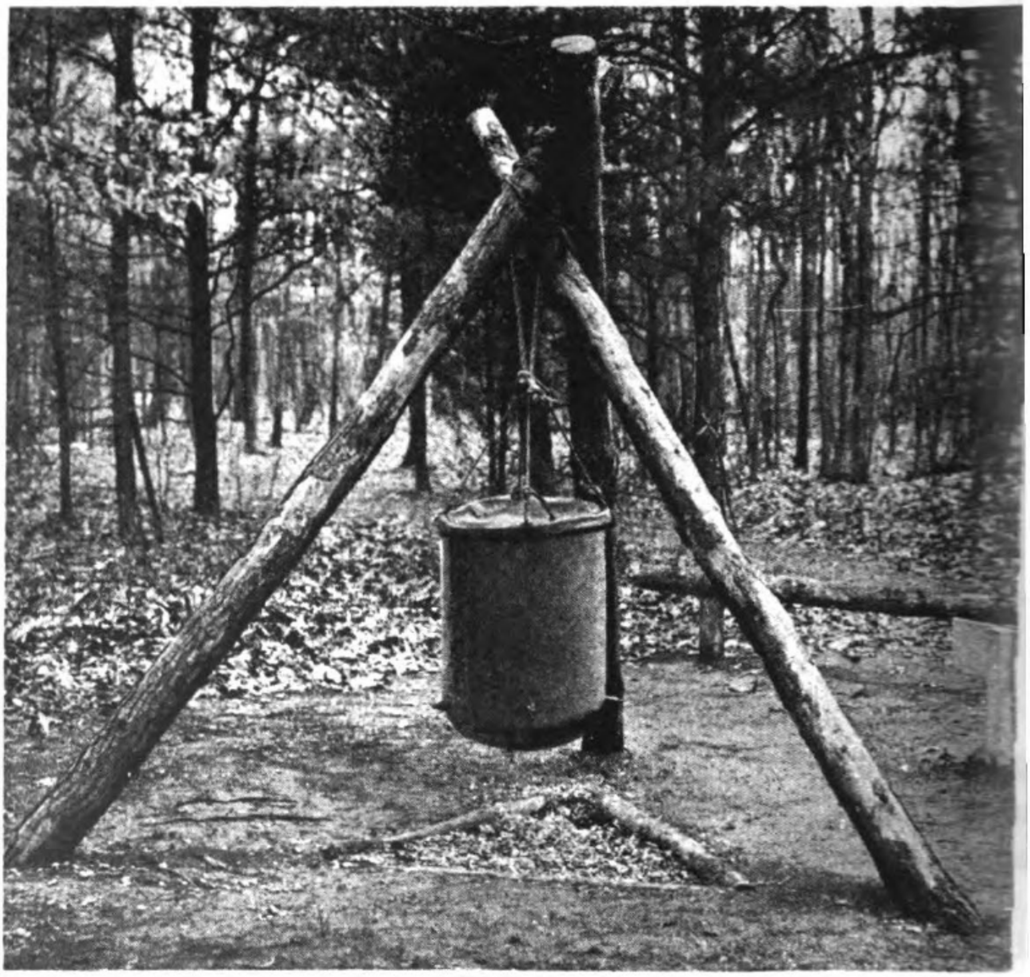


Figure 9–1.—Lyster bag.

amoebic life because of your geographic location or warnings of your medical officer, follow the above basic method. However, after the test at the 10 minute point, add another ampule of calcium hypochlorite and allow a further contact period of 30 minutes before using the water. This method should produce a chlorine residual over 2 ppm. The color comparator discussed in chapter 8 may be used to make the residual-chlorine test.

KIT-TYPE PURIFICATION UNIT

Various types of equipment have been developed for water treatment purposes. One of these is a hand pumping kit-type purification unit which has been designed for the use of small, isolated troop units. It may be used by initial landing units, patrols, parachute troops, or stranded personnel. This unit is durable and easy to operate. It will produce clear filtered water from turbid raw water at the rate of ¼ gpm. It will also reduce the bacteria concentration in the water.

This unit is about 6 inches in diameter and 3 inches in height. It has a small hand-operated diaphragm pump, double-faced filter disk, base, clamping ring, and suction and discharge hoses.

The raw water is drawn by the diaphragm pump through the suction strainer and hose. It enters the unit and is forced through the filter pads on the top and bottom of the filter disk (fig. 9–2). The filtered water then flows to the discharge hose.

You will find it easy to assemble and operate the unit. First remove the filter disk from the pump and base by releasing the clamping ring catch. Place a filter pad on top of the base, put the filter disk carefully on the pad, and then lay another filter pad on top of the disk. Be sure to keep everything clean and to place the smooth side of the filter pads against the disk.

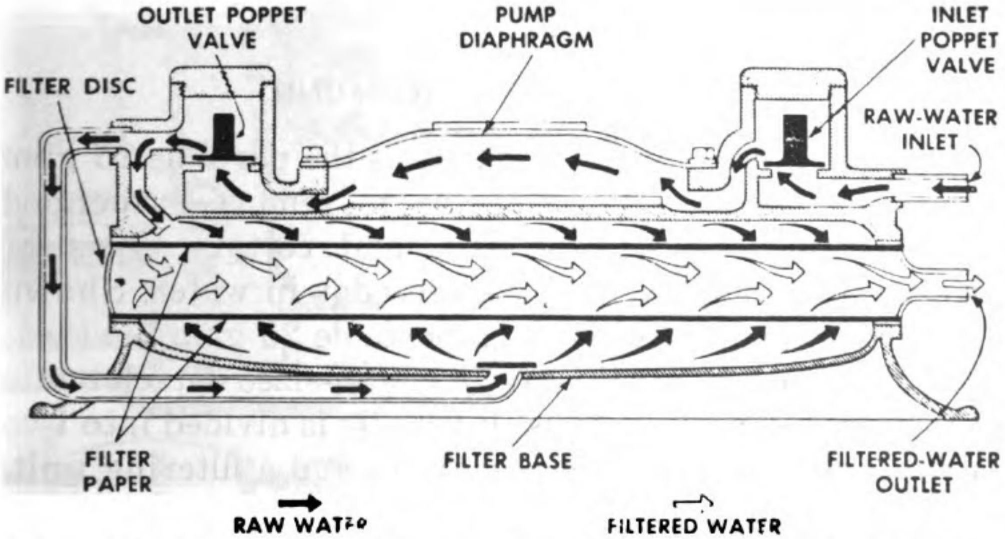


Figure 9–2.—Flow diagram of water through the kit-type purification unit.

The diaphragm pump is put on top of the filter disk and the three parts (base, disk, and pump) are clamped together. If the clamp is too tight or too loose, adjust the clamping ring at the hinge.

After you finish this assembling, check the suction hose to see if it is connected tightly to the unit. Then put the suction strainer in the water so that it will be able to take in water without being clogged by leaves or moss.

Now you are ready to filter raw water. Work the pump lever at the rate of 70 to 80 strokes per minute. If no water is delivered after 1 or 2 minutes, check the strainer and suction hose for clogging or a loose connection to the pump. Also, check the poppet-valve caps for leaks.

The water will flow through the filters and the discharge hose, and you can catch it in canteens or other containers. You are not ready to drink this water yet, as it has to be disinfected with iodine tablets.

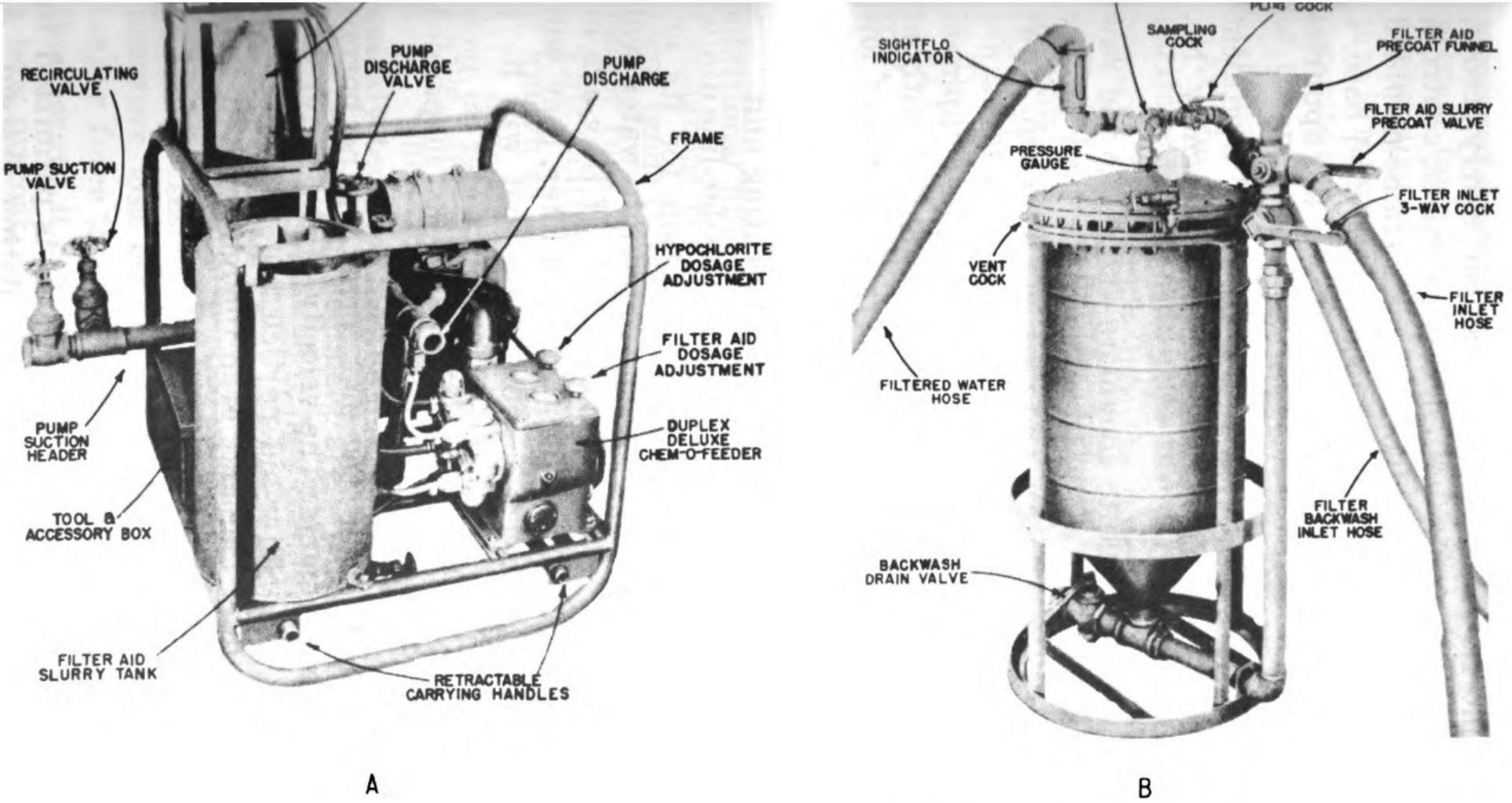
When the flow of water from the discharge hose gets too small, it is time to change the filter pads. Usually, a filter pad set will filter at least 20 quarts of water.

Under the hinge of the pump lever is a small pressure-relief valve. This opens and discharges water if you pump too fast and the water pressure against the filter disk is too high. Slow down on your pumping rate and all will be well.

25 GPM PURIFICATION UNIT

A major water purification item is the portable 25 gpm water purification unit. It helps to remove suspended mineral and organic materials, and certain types of germs, which may cause taste and odor in water. Shown in figure 9–3 is one model of a portable 25 gpm purification unit, which is designed for medium-sized detachments and semipermanent systems. It usually is divided into two parts—a pumping and treating unit, and a filtering unit.

The pumping and treating unit or machinery section is a frame-mounted, gasoline engine-driven unit complete



Courtesy of Proportioneers, Incorp.

Figure 9-3.—25 gpm purification unit. (A) Pumping and treating unit. (B) Filtering unit.

with hypochlorite reservoir, slurry hopper, slurry feeder, pump, hypochlorite feeder with necessary valves, controls, and appurtenances. The filtering unit is a frame-mounted unit consisting of a steel shell attached to a steel base, a steel cover, filter elements, valves, controls, and appurtenances.

The purification unit and a 90-day supply of treatment chemicals are provided in advanced base assembly No. 2138.

It is usually desirable to coagulate and settle the raw water before filtering it. This relieves the load on the filter, increases its capacity, and uses less filter-aid. However, there may not be enough time to set up the tanks required for this purpose. Or, if you move the equipment to another place within a short time, you may do without coagulation and sedimentation. If the raw water is of low turbidity (below 50 ppm) and is free from algae or other slime forming organisms, you can pump the water from the source directly to the pumping and treating unit.

The diatomite filter depends upon the powder-like diatomaceous earth used as a filter-aid solution for its efficiency. These tiny particles when stirred into water will settle to the bottom in the form of a cake. If they are in flowing water which is passing through a filter, they will form a mat of interlaced particles. This mat will have many very fine openings that will permit water to pass through them readily and still catch any suspended particles in the water.

In the diatomite filter, the mat forms on the porous cylindrical filter elements. The velocity of the water and the tendency of the filter-aid particles to interlace hold the mat on the filter elements even though the mat is in a vertical rather than a horizontal position.

Principles of Operation

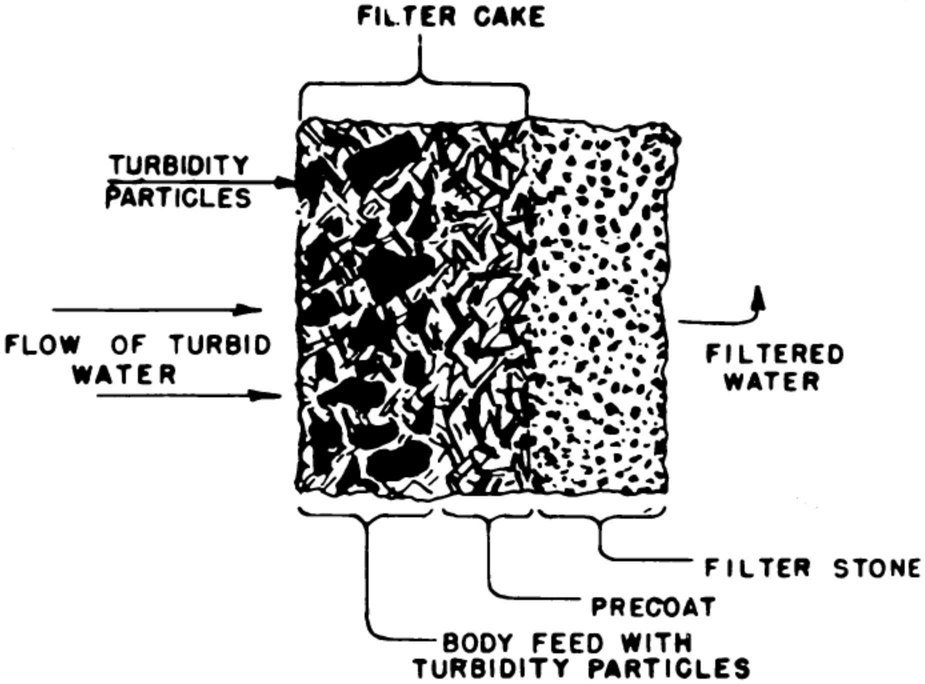
Before starting the filter, clean water is permitted to enter the filter tank and the recirculating system. A measured amount of filter-aid is mixed with water in a precoat tank and pumped or poured into the filter shell (depending on the model of filter being used). The mixture is then recirculated until all of the filter-aid has been deposited on the filter elements, as indicated by the clarity of the recirculating water. This initial filtering mat of diatomaceous earth is known as the PRECOAT.

At the start of this process, some of the smaller particles of filter-aid pass through the elements and are brought back again into the filter tank. As the surface now presented by the mat or cake is of much finer porosity, the small particles are eventually retained on the surface. The precoating operation requires from one to five minutes and is most important.

At the beginning of a filter run, the surface of the precoat is porous. If turbid water were passed continuously through it, the sediment would accumulate on the precoat, gradually stopping up the openings. In most cases, the pores would be clogged in a very short time. Therefore, additional filter-aid powder is introduced into the water throughout the run. The filter-aid mixed with the sediment tends to keep the coat porous and will permit much longer runs at higher rates.

This continuous feed of filter-aid slurry or suspension is known as BODY FEED. The amount of body feed necessary depends upon the nature of the sediment. For example, large, hard particles will tend to maintain an open cake, while soft, slimy, or plate-shaped particles will quickly tend to clog the filter mat. Figure 9–4 illustrates how particles of sediment are separated by the filter-aid body feed and allowed to flow through.

As the turbid water and the filter-aid flow through the filter and leave suspended particles on the filter cake, more and more resistance is offered to the flow. Finally, the pressure loss becomes so great that the pump will no longer force the water through at a desirable rate. When this occurs, it is necessary to BACKWASH the filter, apply a new precoat, and start over.



PARTICLES OF TURBIDITY IN FILTER CAKE SEPARATED BY FILTER AID BODY FEED ALLOWING PASSAGE OF WATER. WITHOUT BODY FEED THESE PARTICLES JOIN TOGETHER AND STOP FILTRATION.

Courtesy of Proportioneers, Incorp.

Figure 9–4.—Filter-aid principle.

If it is necessary to furnish a maximum amount of water in a minimum of time, the unit may be operated only at high rates and backwashed more frequently. It is better, however, to operate for longer periods at lower rates as this saves filter-aid.

The diatomite filter operates at much higher rates and at much higher pressure losses than sand filters. It can be backwashed at any time considered desirable. The backwash consists of three operations.

1. Loosening of the precoat and filter cake.
2. Flushing out of the sludge.
3. Actual backwashing of the filter elements and the filling shell with filtered water.

Methods used to perform these operations will be outlined in detail later.

In portable units, chlorine is used in the form of calcium hypochlorite powder which contains 70 percent, by weight, of available chlorine. The normal dosage varies from one to several parts per million. Water must be chlorinated before it is considered safe to use.

The average water can be treated with 1½ ppm of available chlorine, and an excess of approximately 1 ppm will be left in the water. The minimum chlorine residual is prescribed by the medical officer in charge. It serves to eliminate any bacteria which may pass through the filters.

Operating Procedures

Before starting the filter unit, see that the engine crankcase is filled with oil. Use medium oil in summer and light oil in winter. The gasoline tank should be filled with a high grade gasoline. Do not start the engine before the pump is primed. To fill the pump with water, remove the prime plug on top of the pump casing.

Follow the directions furnished with each unit for filling the hypochlorite reservoir.

In starting the diatomite filter, the recirculating tank and the filter shell should be filled with distilled or purified water or the clearest water available. If you believe that the raw water is badly polluted, use clean sea water instead. This is important, because disease germs might get into the filter stones and into the filtered-water tanks.

Precoating

Precoating procedures vary considerably with the model of equipment provided, and since different models of equipment employ somewhat different operations for precoating, a single fixed procedure can not be stipulated. The manufacturer's instructions furnished with each unit outline the exact procedure of operation for the particular type of equipment and should be followed diligently. In general, the precoating procedure consists of the preparation of the slurry and the recirculation of this slurry through the filtering unit, for the purpose of building up a cake of diatomite filter-aid on the filter elements to screen out suspended matter and organisms from the water being treated.

While recirculating, check the slurry rate of the feeder. Also, make up the filter-aid slurry for the body feeder and start the body feed. It is important that flow be maintained through the filter section between the precoat and filter operations to prevent the filter cake (precoat) from dropping off the elements.

Filtration

You are now ready to adjust the filter-aid feeder settings for regular filtering purposes. Make up a supply of slurry by measuring out the proper amount of filter-aid and mixing it with water in a clean can.

For 2½ percent slurry or suspension, mix 1 lb and 1 oz in 5 gals of water.

For 5 percent slurry, mix 2 lbs and 2 ozs in 5 gals of water.

For 7½ percent slurry, mix 3 lbs and 3 ozs in 5 gals of water.

When thoroughly mixed, pour the slurry into the slurry tank through the screen cover, and vent the air from the feeder head by loosening the vent screw in the check valve cap. Set the stroke length adjustment of the filter-aid feeder for the proper feed, dependent on the turbidity of the raw water.

In addition to the slurry, you will have to prepare a hypochlorite solution. Fill the hypo reservoir or hypo bag (capacity 5 gals) half full of water and add the required number of ounces of hypochlorite.

For 4 ppm chlorine dosage, use 0.2 percent solution—dissolve 2 ozs hypochlorite in 5 gals water.

For 2 ppm, use 0.1 percent solution—dissolve 1 oz hypochlorite in 5 gals water.

For 1 ppm, use 0.05 percent solution—dissolve 0.5 oz hypochlorite in 5 gals water.

Fill the hypo reservoir or bag to within 3 inches of the top and set the hypochlorinator at the maximum stroke. After priming has been completed and the feeding is proceeding properly as observed through the sight feeder, reduce the setting by adjusting the rate of the feed controller.

You are now prepared to filter the raw water. Open the raw water suction valve and close the recirculating valve on the suction header so that the pump suction is shifted from the recirculating tank to the raw water source.

Transfer the filtered water discharge hose from the recirculation tank to the filtered water tank after the recirculation tank starts to overflow. If salt water has been used for the initial filling, continue to overflow the recirculating tank until the water no longer tastes salty.

The raw water turbidity should be checked occasionally to ensure that it has not changed.

As the cake of sediment and filter-aid builds up on the filter stones, the pressure loss across the filter will rise, and it will be necessary to adjust the filter effluent valve to maintain the rate, until the valve is wide open. Thereafter, as the rate of flow falls, the dial settings on the filter-aid feeder and the hypochlorite feeder should be reduced to maintain the proper dosage. The filter-aid feeder should not be reduced below 2 scale dimensions; and when that setting is reached, it should be left at that point. The hypochlorite feeder setting may be reduced all the way to zero.

Backwashing

Backwashing consists of removing the filter cake and accumulated suspended matter from the filter elements. Backwashing and flushing of the filter should be accomplished when the filter run is stopped (as determined by pressure drop) and at the end of each day's operation.

A method for backwashing one type of unit is as follows: To remove the precoat and filter cake from the filter stones, build up a fairly high pressure on both sides of the stones. Then, suddenly release the pressure on the outside of the stones. When the pressure is released, it causes a sudden flow at a high rate through the stones from the inside outward, kicking the cake loose. The pressure is built up by first closing the filter effluent valve and setting the filter inlet 3-way plugcock so that the water cannot flow into or out of the filter. You then open the backwash inlet plugcock, allowing the pressure from the booster pump to be applied on the filter. Figure 9–5 shows the valve positions for these operations.

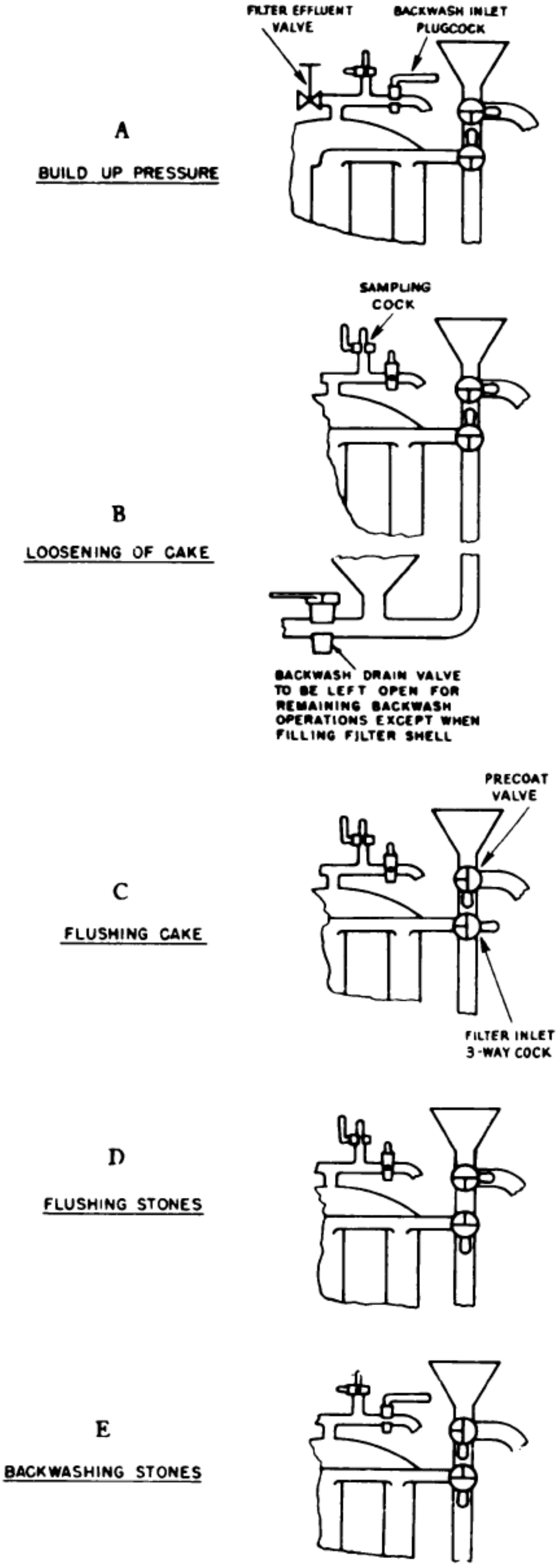
To loosen the cake on the outside of the stones, you open the backwash drain valve quickly, and immediately thereafter you close the backwash inlet plugcock. The backwash drain valve is left open for the other backwash operations except when filling the filter shell. Open the sampling cock (see fig. 9–5 (b)).

You will need to flush out the sludge that you now have in your unit. Set the precoat valve to the precoat position and the filter inlet 3-way cock so that air can enter both the filter head and the bottom of the filter (see fig. 9–5 (c)). Do this as quickly as possible after the cake is loosened.

At times, some of the cake will stick to the stones. However, the stones can be flushed with raw water from the pumping and treating unit, and in this way the remainder of the cake is dislodged and carried out to waste.

For this flushing operation, set the precoat valve so that raw water can enter the filter. Also set the filter inlet 3-way cock so that the water can enter the filter head only (see fig. 9–5 (d)). Open the treating unit pump discharge valve and flush for 2 or 3 minutes. Then close the valve again.

Most likely you will want to backwash the filter stones and clean them from the inside outwardly. To do this, you



Courtesy of Proportioneers, Incorp.

Figure 9–5.—Backwashing the filter unit.

set the precoat valve to the open position and close the sampling cock. Then open the backwash inlet plugcock and allow the clean water to backwash the filter stones to waste for 1 or 2 minutes (see fig. 9–5 (e)).

The filter unit should be cleaned through these backwashing operations. To refill the filter and make it ready for a new precoat, close the backwash drain valve and open the backwash inlet plugcock. When the filter is full, shut the plugcock again.

The backwashing of another model of filter is accomplished in the following manner: The filter outlet valve is closed to allow the filtered water pressure to increase and thus compress the air trapped in the air bells of the filter elements. When the air release valve is opened an instantaneous loss of pressure occurs in the filter shell, and the air trapped in the air bells expands outward through the filter elements. This instantaneous outward push breaks the filter cake from the elements. The broken cake is then flushed from the unit. Unfiltered water should never be permitted to get inside the filter elements as this would cause coating of the interior with suspended matter, which would be difficult or impossible to remove.

Securing the Unit

When you secure the unit for the night, or for any extended period between runs, follow these steps:

1. Backwash the filter thoroughly.
2. Drain the filter-aid slurry tank.
3. Refill the slurry tank with clean water.
4. Loosen the air valve screw in the filter-aid feeder check valve cap, open the precoat valve, and operate the pumping and treating unit until the water in the filter-aid feeder becomes clear.
5. Shut off the pumping and treating unit, remove the check valve from the filter-aid feeder and wash them out in clean water.

6. Drain the filter-aid slurry tank.
7. Refill the gasoline tank.
8. If there is any danger of freezing, drain the entire unit including the filter, hypochlorinator, auxiliary pumps, and hose lines.

Maintenance

Too much emphasis cannot be placed on preventive maintenance as well as proper operation of the equipment you will be using. Advanced base equipment cannot be replaced easily. In most cases, it must be repaired on the spot if something goes wrong. Equipment manufacturers have excellent catalogs containing specific maintenance instructions for the individual parts of the equipment. In this training course, previous chapters have already discussed the care of pumps and engines.

Lubrication of the pump, engine, hypochlorinator, and slurry feeder is of primary importance to efficient operation. Care should be taken to ensure use of proper lubricants and changes of engine oil as recommended by the manufacturer of the equipment.

The filter-aid slurry tank agitator has a 40-mesh screen cover. This is to be used at all times. The agitator shaft does not need to be lubricated as all bearings are of the self-lubricating type. The bevel gear housing should be greased and half-filled with a good grade of gear lubricant each month. The lubricant is smeared on the gears after removing the housing caps.

No maintenance of the filter stones is necessary except when pressure loss becomes excessive due to clogging. Then the filter stones should be cleaned. The filter stones are removed from the plate and dipped in a solution of nitre cake for 10 minutes.

They are next dipped in a solution of soda ash. After all four stones have been so treated, they are rinsed thoroughly with clean filtered water. If necessary, repeat the cleaning and rinsing operation using the same solutions.

Sometimes the water being treated is excessively hard and will clog the filter stones by building up a layer of calcium carbonate or lime on them. To remove coatings of this type, shut off the filter and add enough sulfuric or hydrochloric acid or sodium acid sulfate to the water in the filter tank to make a 1 percent solution. Allow the solution to stand for a time and then drain it and wash the filter.

Wire-wound filter elements will, under certain conditions, require cleaning with a brush for removal of filter cake. To remove filter elements, first remove the upper half of the filter section exposing the elements; then remove the elements by lifting each element from its adapter. Clean the elements by scrubbing with a wire brush and rinsing in clear water.

The Sightflo Indicator must be kept clean if it is to record the rate of flow accurately. Periodically, it is necessary to disassemble the parts and to clean them thoroughly.

HYPOCHLORINATION UNIT

Hypochlorination units are major water treatment items, used primarily at large advanced base establishments. They are designed to chlorinate water automatically. This is important where the water requires chlorination only, and rate of flow of the water being treated is likely to vary.

The unit issued to advanced bases is complete with a by-pass fitting set and has a capacity of 2 to 100 gals per minute when installed in the line, and a capacity of 2 to 400 gpm when installed as a by-pass. (See fig. 9–6.) It is used where the raw water supply is clear and found to be free from harmful amoebic cysts.

The unit is usually mounted on a pipe frame with skids. Its main parts are a hydraulically operated hypochlorinator, a water meter, a manual range adjusting valve, and a pressure regulating valve.

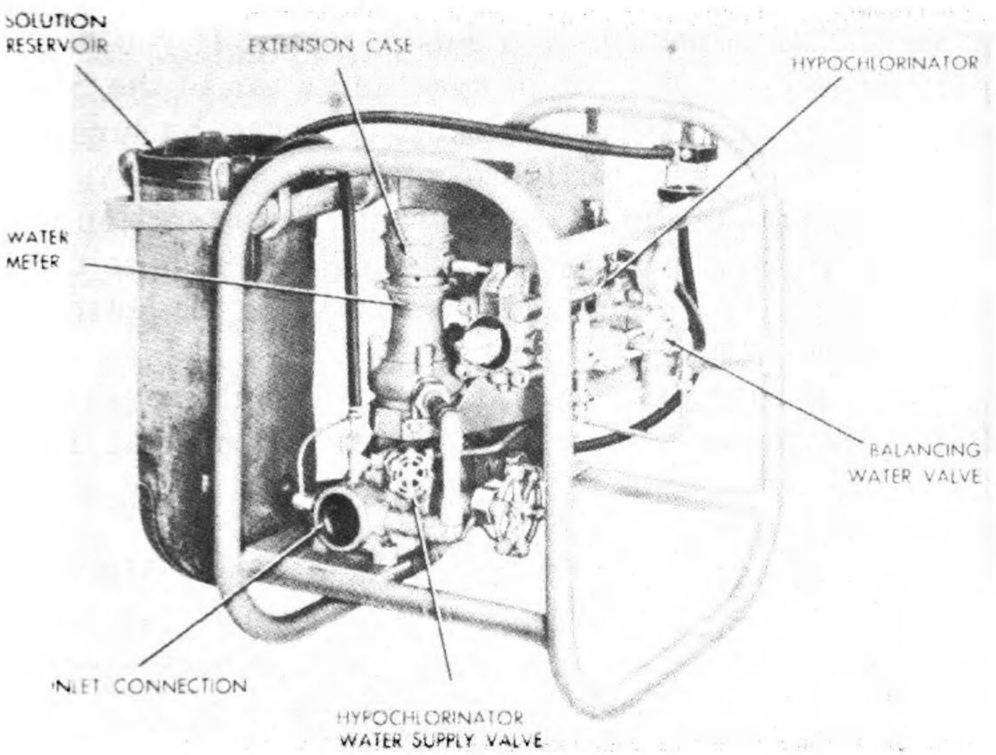


Figure 9–6.—Portable automatic hypochlorination unit (left front view).

The hypochlorinator pumps the hypochlorite solution into the water at a rate governed by the speed of the water meter. The water meter is operated by a small flow of water which is diverted from the main line by means of the manual range adjusting valve. The water pressure regulating valve maintains a water pressure in the system of at least 10-pounds per square inch so that the hypochlorinator can be operated satisfactorily.

Operating Procedures

Before starting the hypochlorination unit, you should check it for any damage or leakage. Also check to make sure that there is an adequate supply of hypochlorite solution in the reservoir. If necessary, make up some new solution.

For a new solution, high test hypochlorite powder is added to clear water in the solution reservoir. If the maximum flow to be treated is near 100 gpm, add 10 ozs of hypochlorite powder to 5 gals of water. If you anticipate a maximum flow of 50 gpm, add 5 ozs to the 5 gals of water. If any extra chemical is left over, be sure that you store it in a dry, airtight container.

Now check the end of the hypochlorinator suction hose to see that the strainer is installed. Place the hose in the solution reservoir so that the strainer is at the bottom of the reservoir.

Your operating duties will be mostly valve adjusting. Set the hypochlorinator stroke control handle at 10 on the dial. Open wide the hypochlorinator water supply valve and the manual range adjusting valve.

Check to see that the water pressure gage on the hypochlorinator registers at least 9 to 10 pounds per square inch. See that the flow controller needle is open about ¾ of a turn from its dead shut-off position.

Adjust the range adjusting valve so that the hypochlorinator runs at a speed of 12 strokes per minute when the maximum flow is reached. The maximum flow should not exceed 100 gpm.

Check to see that the hypochlorinator is primed. When properly primed, the hypochlorite solution should spurt into the sight glass during every suction stroke of the hypochlorinator. Usually the machine will be self-priming. The air vent on the sight glass must be closed when the hypochlorinator is running. If the unit cannot be primed, check the hypochlorinator suction line for air leaks.

After you have performed these operations, you will have little to do in operating the unit. Your chief duty will be to make up a new batch of hypochlorite solution whenever the level in the reservoir drops to within 2 or 3 inches of the strainer.

There are two things to consider in determining the amount of chlorine to be added to the water: one is the volume of hypochlorite solution used, and the other is the strength of the solution. For example, 60 gals of 0.5 per cent hypochlorite solution contains the same amount of chlorine (2.5 lbs) as 30 gals of 1 percent solution.

If the volume of water being treated requires 2.5 lbs of chlorine per day, you may use either the 60 gals per day of 0.5 per cent hypochlorite solution or the 30 gals per day of 1 per cent solution.

At a speed of 12 strokes per minute, the hypochlorinator will pump 60 gals of solution per day when the stroke control handle is set at 10 on the dial. In general, it is more desirable to operate the hypochlorinator with a weak solution and a long stroke rather than with a strong solution and a short stroke. In the example, therefore, the 0.5 per cent solution would be preferable.

If the water used to mix the sterilizing solution contains "hardness," it is advisable to add some soda ash to the solution. This will result in the precipitation of the "hardness" and the precipitate should be allowed to settle to the bottom of the reservoir. The amount of soda ash to use is best determined experimentally by observing the precipitate.

The shut-down of the unit is more or less automatic in that the hypochlorinator will stop when the water stops flowing through the main under treatment. Remove the hypochlorinator suction hose and strainer from the solution reservoir when you take the unit out of operation.

If the unit is to be removed for storage or shipment, or is to be exposed to freezing temperatures, all water must be drained from the hypochlorination unit. It is particularly important that all solution be drained from the hypochlorinator pumping block by removing the pumping block and poppet valves. The sight glass and solution reservoir should also be drained.

Maintenance

There is little to do in the maintenance field. No lubrication is required for this unit. While the machine is running, check the water pressure gage and the sight glass frequently. The pressure should not be less than 9 to 10 pounds. You should be able to see the solution spurt into the sight glass on every suction stroke of the hypochlorinator. At the first sign of failure, stop the unit and locate and correct the trouble.

Every few hours check to see that there is an adequate supply of hypochlorite solution in the reservoir. If necessary make up some new solution. Test the chlorine residual frequently.

After the unit has been shut down, make sure that the hypochlorite suction hose and strainer have been removed from the solution reservoir. If necessary, clean the strainer. Also examine the balancing water valve strainer and clean it if necessary.

SUPERCHLORINATION

There are various types of chlorination, and the type used at any installation should always be approved by the district public works officer or the CEC officer assigned this responsibility. One type which you may use frequently in your work is known as SUPERCHLORINATION. This means the application of more chlorine than is needed to maintain the proper chlorine residual, followed by dechlorination to remove the surplus. Superchlorination is particularly valuable in surface water of variable ammonia and organic content. Sulfur dioxide reacts with water to form acids that are neutralized by the natural cell salinity of the water. Sulfur dioxide is fed by equipment similar to that used for chlorine. Activated carbon absorbs excess chlorine, while aeration disperses it in the atmosphere.

DECONTAMINATION OF WATER

Sometimes it may be necessary to purify water contaminated by chemical warfare agents, biological warfare agents, or radiological warfare. Before treatment is considered, however, every effort should be made to procure an uncontaminated source of water, or to have containers of potable water hauled in. The testing and treatment of contaminated water must be closely supervised by the local medical officer. Only personnel who have been trained in water purification should be permitted to participate in water decontamination.

Chemical Decontamination

The Bureau of Medicine and Surgery has provided a water testing and screening kit for use in detecting chemical warfare agents in water. The kit includes chemical reagents, accessories, instructions and containers. It is possible to detect any presently known chemical warfare agents in water, including nerve gases or G-agents (organo-phosphorous compounds).

There is also available a water testing kit, for poisons. This kit is used to determine the quantity of chemicals required to decontaminate the water. The same test must be applied to determine the effectiveness of the decontamination procedure.

Large volumes of contaminated water can be treated at established water treatment plants. The general procedure is as follows:

(1) The water to be decontaminated is first withdrawn from the intermediate levels of the supply to minimize surface and bottom disturbances.

(2) A QUANTITATIVE analysis of the CW agents is made because further treatment depends on the contamination agent as well as the amount of agent present.

(3) If a G-agent is present, soda ash is added to the water, which is then agitated. Alum is added and after further agitation, the water is allowed to settle. It is then run through a water purification unit and a final quantitative chemical analysis is made.

(4) If other than G-agents are present, the water is treated with activated carbon. The amount of activated carbon used will vary, depending on the nature and amount of the agent. After mixing, a coagulant is added,

which, upon further mixing, is allowed to settle. The mixture is then run through a water purification unit and a final quantitative chemical analysis is made.

Small volumes of contaminated water can be treated by using two Lyster bags. If quantitative testing equipment is available, the identity and the concentration of the agent can be determined. This will enable the correct amount of activated carbon or soda ash to be added to the water in one Lyster bag. However, if the identity and concentration of the contaminants are unknown, 2 pounds of activated carbon and 2 ounces of soda ash should be added to the water in one Lyster bag. After stirring for 20 minutes, an ounce or more of alum is added. After further stirring, the mixture is allowed to settle. It is then siphoned through a filter to the second Lyster bag. The water is now ready to be tested with the water testing and screening kit. If the tests are negative, the water is ready to be chlorinated.

Biological Warfare Decontamination

The detection of biological contamination of water and the laboratory analyses are responsibilities of the medical department. However, the public works officer, or other CEC officer, may be called on to assist in the collection of water samples and, perhaps, in the decontamination process itself.

In the decontamination process, more chlorine probably will need to be added than during the ordinary process of the water. If no water treatment facilities are available, water can be decontaminated by boiling for 20 minutes, by distillation if equipment is available, or by using iodine tablets coupled with boiling.

A medical officer should pass on the method and the completeness of the decontamination process before any water is used for drinking purposes. Water that has been decontaminated must, of course, be protected against further contamination.

Radiological Decontamination

Radioactive contamination from an atomic blast consists of finely divided radioisotopes which become attached to dust particles or water droplets. Such radioactive material behaves physically like other dirt or moisture.

When radiological contamination is present in the water source, consumption after treatment must be held to a minimum for at least one month after the blast. This time will reduce the number of radioisotopes which have a short half-life, thereby reducing the possibility of radioactive injury. At present, there appears no treatment that will ensure complete removal of radiological contamination from large quantities of water. Perhaps new developments will make possible such a treatment in the near future; meanwhile, use the following as a guide.

Coagulation, sedimentation, and filtration, if properly performed, will remove approximately 70 percent of all radioactive material. Use 100 ppm of local clay, 25 ppm of alum, and 18 ppm of soda ash in the coagulation tank. Rapid mixing of the chemicals and clay in the raw water for 30 minutes, then allowing another 30 minutes for settling, should be sufficient. After filtration, test the effluent with a waterproof Geiger-Mueller tube immersed in the water, or by some other approved means. If it is above the prescribed tolerance for drinking water, the raw water must be coagulated and settled again in a second tank before it is filtered.

Warning

All water must be filtered and chlorinated before it is used, regardless of previous treatment for decontamination.

Need for Preparedness

In the event of biological, chemical, or atomic warfare, a supply of safe water will have a vital effect on the survival of human lives. This is a matter of chief concern to the Utilities Man. Therefore, it is to your advantage to be prepared to meet such a situation. In case you can spare the time for some additional study on your own, here are three excellent references that should prove helpful: *Chemical Warfare Defense,* TP–PL–3; *Biological Warfare Defense,* TP–PL–4; and *Atomic Warfare Defense,* TP–PL–2.

QUIZ

1. What is the primary purpose of a Lyster bag?
2. What type of filter is used in the kit-type purification unit?
3. When using the 25 gpm purification unit, why is it generally desirable to coagulate and settle the raw water before filtering it?
4. On what does the diatomite filter depend for its efficiency?
5. What is the precoat in the operation of a diatomite filter?
6. Why is body feed used during the filter run?
7. What are the three operations involved in backwashing the diatomite filter?
8. As the rate of flow falls in a diatomite filter run, what do you do to the filter-aid and hypochlorite feeders?
9. What is the first step recommended in securing a diatomite filter?
10. What is the capacity (in gpm) of the hypochlorination unit issued to advanced bases, when installed as a by-pass?
11. What is the minimum recommended water pressure in a hypochlorination unit?
12. What is the recommended speed for a hypochlorination unit when maximum flow is reached?
13. What is used to precipitate "hardness" of water?
14. At a speed of 12 strokes per minute, how many gallons of solution per day will the hypochlorinator pump when the dial reading of the control handle is set at 10?
15. What does the term superchlorination mean?

CHAPTER 10

DISTILLATION UNITS

Distillation is a method of changing water into steam by means of heat and changing the steam back into water by condensation. This process removes impurities and makes even sea water fit for drinking. The ultimate product resulting from condensation is called DISTILLATE.

Since distillation is an expensive process, it is used only when other methods of obtaining drinking water are not possible—for example, when the only available water supply is sea water.

In nature, distillation is carried out on a huge scale. Water evaporated from the surface of the earth is condensed in the cool atmosphere and is precipitated in the form of rain or snow. Science has benefited considerably from nature's method of distillation. Man could not live were it not for this distillation.

COMPRESSION DISTILLATION

Theoretically, in compression distillation no direct heat is applied to the liquid except to start the process. The heat to continue the process is generated by compressing the vapor to a higher pressure and temperature and discharging it back to the heating element of the same distillation unit (still). Heat which is given up through the discharge of distillate, radiation, and other causes is replaced by utilizing the raw water taken into the system, a compressor, and auxiliary heat. The temperature in this process is indicated in degrees Fahrenheit, and the pressure in pounds per square inch (psi). Psi is measured on standard gages and is indicated 0 psig, 1 psig, etc. Thus, a reading of 10 psig indicates that the gage reads 10 pounds per square inch.

85 GPH DISTILLATION UNIT

The 85 gallon per hour (gph) distillation unit, model DVC–8, is one type of unit commonly used by the Seabees. (See fig. 10–1.) It is skid-mounted and has an operating weight of 4,200 pounds. Its over-all length, height, and width are 90, 56, and 58 inches, respectively. Output is 1 gallon of distillate for each input of 2 gallons of raw water. Operated according to instructions, this unit can run continuously, maintaining specified output, for a maximum of 720 hours without shutdown for maintenance and lubrication.

Principal Components

The essential components of the DVC–8 are: EVAPORATOR, HEAT EXCHANGER, VAPOR COMPRESSOR, DIESEL ENGINE, PUMPS, PIPING, GAGES, and CONTROLS.

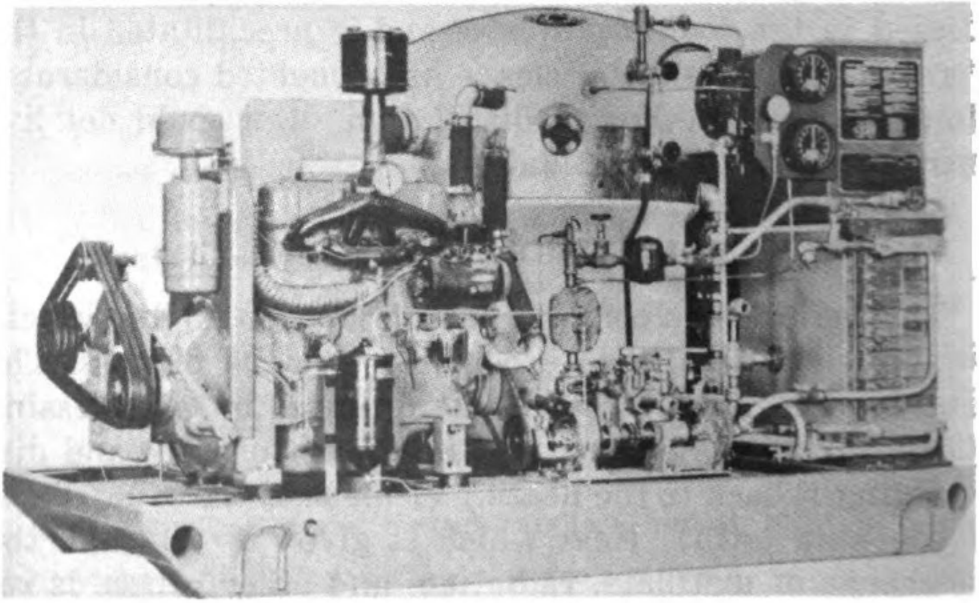
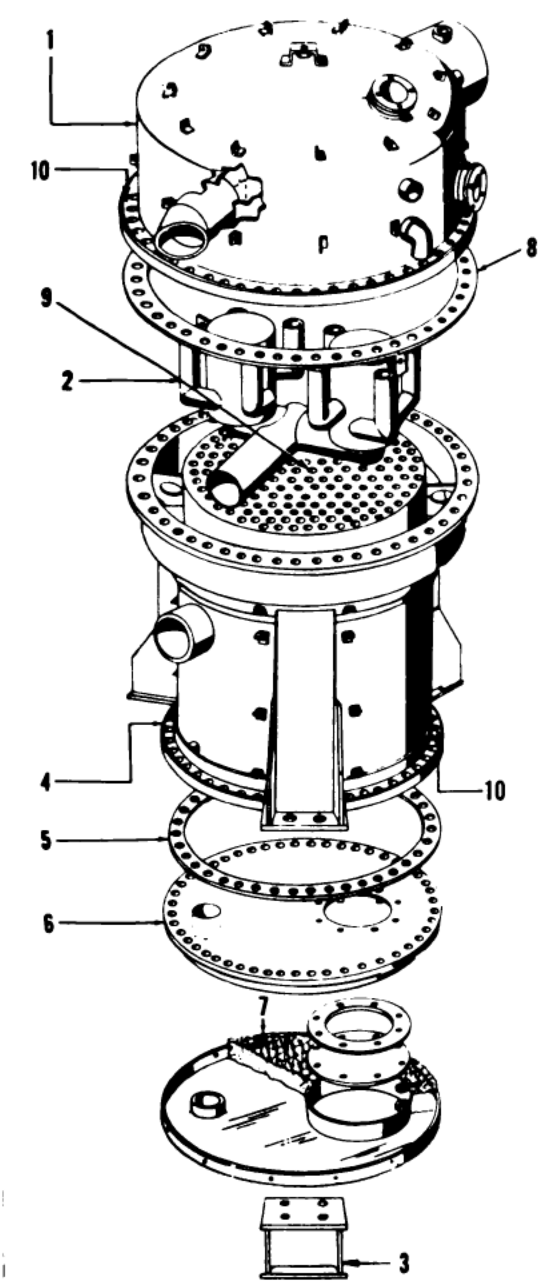


Figure 10–1.—85 gph distillation unit, Model DVC–8.

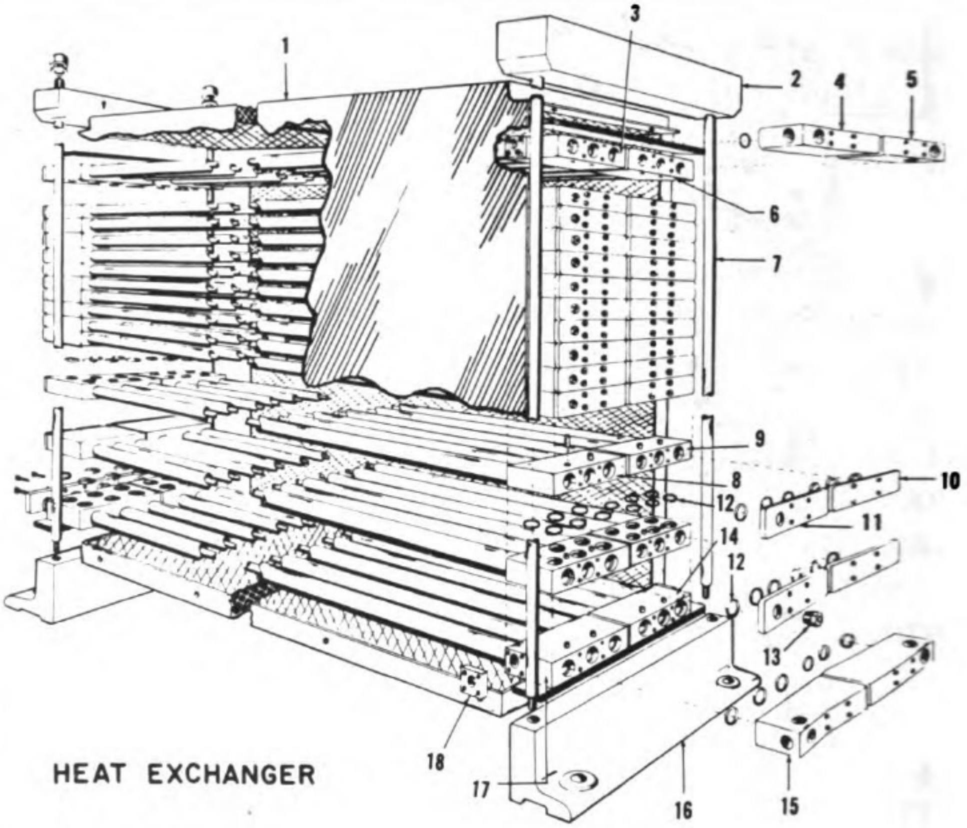


EVAPORATOR ASSEMBLY

1	Vapor Head Assembly
2	Cyclone Steam Separator
3	Support, Evaporator
4	Evaporator Shell Assembly
5	Gasket, Bottom Head
6	Bottom Head
7	Insulation, Bottom Head
8	Gasket, Vapor Head
9	Tubes
10	Back–Up Ring, Top & Back–Up Ring, Bottom

Figure 10–2.—Evaporator assembly.

The evaporator (fig. 10–2) furnishes the heat transfer surface in the form of tubes for vaporizing the raw water and condensing the resulting steam to form the distillate. Raw water in the tubes is brought to boil by external heat, thus producing steam which is recirculated back into the



1	Jacket – Insulated	10.	Cover–Blind
2	Bar – Tie	11	Cover–Distillate Bleeder
3	Section – Tube, Top Left	12	"O" Ring
4	Cover–Distillate, Outlet	13	Valve – Bleeder
5	Cover–Blowdown, Inlet-Outlet	14	Section – Bottom Tube, Right
6	Section-Tube, Top Right	15	Cover–Distillate, Inlet
7	Rods – Tie	16	Base
8	Section–Intermediate Tube, Left	17	Section–Bottom Tube, Left
9	Section–Intermediate Tube, Right	18	Adapter

Figure 10–3.—Heat exchanger.

evaporator via a vapor compressor, where its temperature is increased. The steam condenses on the outer surfaces of the tubes, transferring its latent heat through the tube walls to the boiling water inside. The condensed steam collects on the bottom tube sheet, flows into the distillate line, then to the heat exchanger. Since the latent heat of the steam is recaptured in the evaporator and put to use boiling other water, only a small amount of additional external heat is needed to make up for the heat losses in the system. The evaporator consists principally of an evaporator condenser section (vertical tubes which provide the heat transfer surface), a vapor head (which incorporates a cyclone steam separator to separate entrained water particles from the steam), a bottom head (which serves as a storage well for the feed water), and various control devices such as a pressure gage, liquid level control, and gage glasses to indicate the water level.

The purpose of the heat exchanger is to heat the incoming raw water so that less heat will be needed inside the evaporator, and the plant will be more efficient. The sections in the heat exchangers consist of sets of concentric tubes. The raw water flows into the outer tube; blowdown or distillate flows within the inner tube.

The vent condenser also has two functions: (1) to remove noncondensable gases from the distillate, and (2) to reclaim some of the heat of the noncondensable gases and to transfer the heat to the feed water which flows through the internal tubes.

The vapor compressor draws the steam from the vapor head, compresses it, and forces it into the steam chest in the evaporator shell. This operation increases the pressure of the steam, thereby raising the steam temperature and adding to the latent heat of the steam the amount of heat necessary to vaporize more of the feed water in the tubes, thus inducing a continuous flow of steam through the compressor and back into the steam chest.

The diesel engine serves as a prime mover for the compressor and pumps; it also serves as the original source

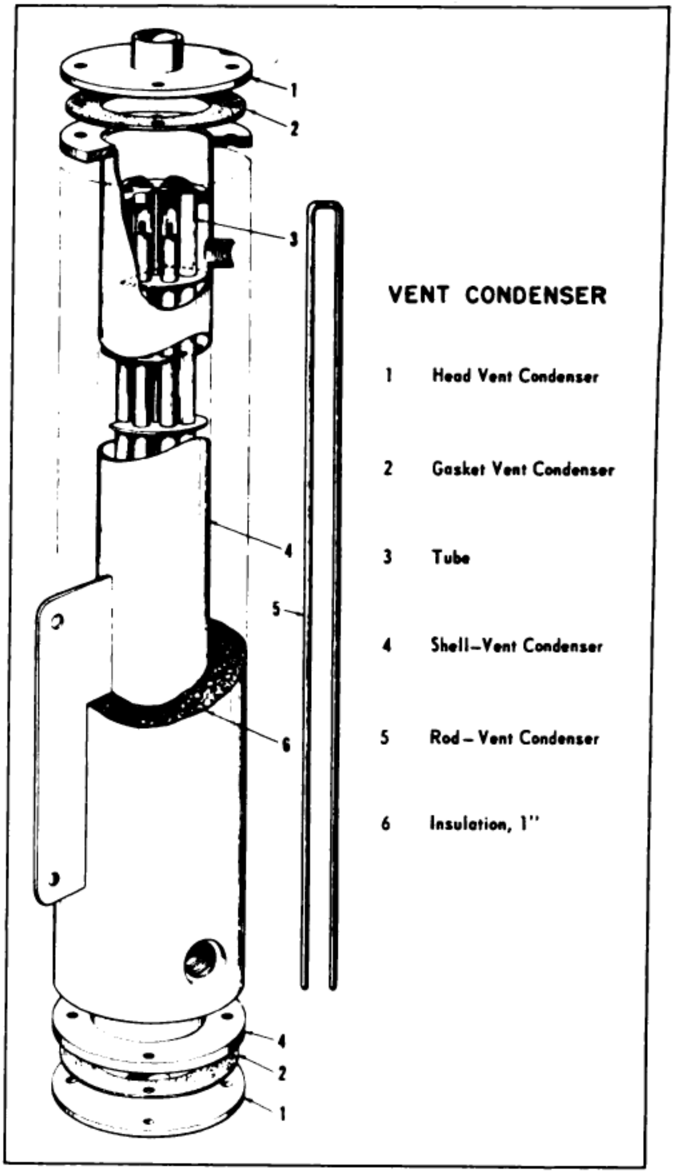
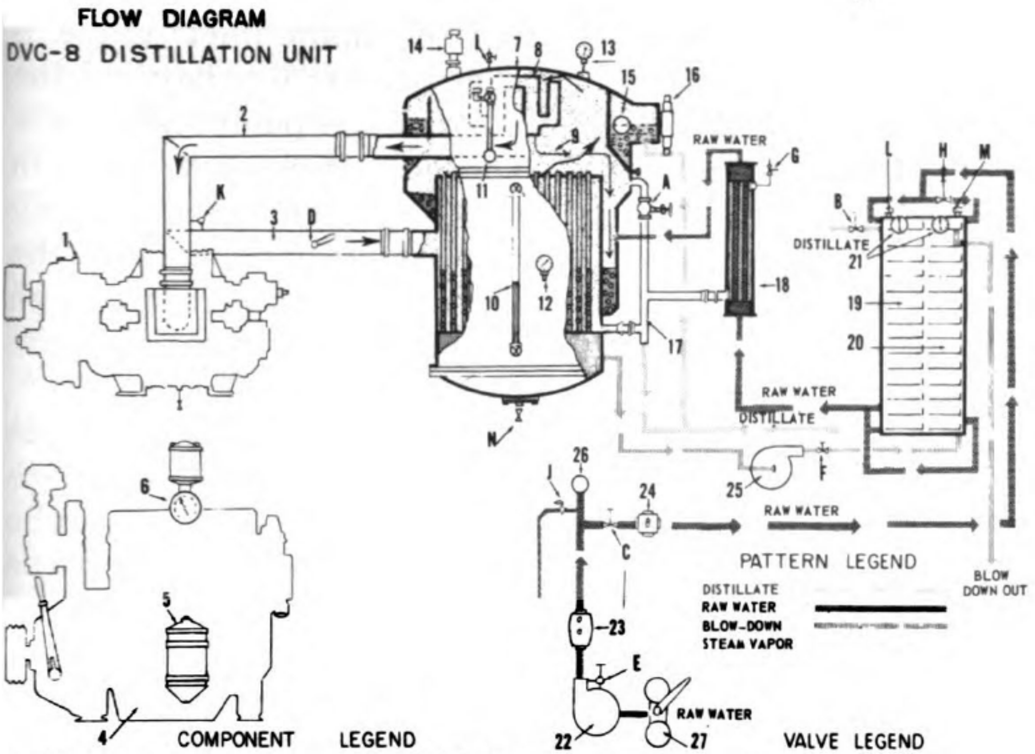


Figure 10–4.—Vent condenser.

of heat which is controlled by setting valve *D* (fig. 10–5). Power from the engine is transmitted through sheave and belt drive assemblies. Follow the detailed instructions of the manufacturer concerning the method of starting and servicing the diesel engine.

There are three piping systems in this distillation unit —raw water, blowdown, and distillate. Besides the pipes and pipe fittings, these systems consist of pumps,



COMPONENT LEGEND

1	COMPRESSOR
2	SUCTION, VAPOR DUCT
3	DISCHARGE, VAPOR DUCT
4	ENGINE
5	OIL FILTER
6	THERMOMETER, ENGINE EXHAUST
7	EVAPORATOR
8	STEAM SEPARATOR
9	DRAIN TUBE-STEAM SEPARATOR
10	EVAPORATOR GAGE GLASS
11	ENGINE BOILER GAGE GLASS
12	PRESSURE GAGE, EVAPORATOR
13	PRESSURE GAGE, VAPOR HEAD
14	RELIEF VALVE
15	ENGINE BOILER
16	WATER LEVEL CONTROL, ENGINE BOILER
17	DISTILLATE HOTWELL AND BY-PASS
18	VENT CONDENSER
19	HEAT EXCHANGER, DISTILLATE-RAW WATER
20	HEAT EXCHANGER, BLOWDOWN-RAW WATER
21	THERMOMETER
22	RAW WATER PUMP
23	OIL COOLER
24	FLOW INDICATOR, RAW WATER
25	BLOWDOWN PUMP
26	PRESSURE GAGE, PUMP
27	STRAINER, RAW WATER

VALVE LEGEND

A	BY-PASS LINE VALVE
B	DISTILLATE DISCHARGE VALVE
C	RAW WATER INLET VALVE
D	COMPRESSOR BUTTERFLY VALVE
E	RAW WATER PUMP BY-PASS VALVE
F	BLOWDOWN DISCHARGE VALVE
G	VENT CONDENSER VENT VALVE
H	HEAT EXCHANGER BY-PASS VALVE
I	ENGINE BOILER VENT VALVE
J	FEED PUMP COOLING VALVE
K	COMPRESSOR FLUSHING VALVE
L	HEAT EXCHANGER DISTILLATE VENT
M	HEAT EXCHANGER BLOWDOWN VENT
N	EVAPORATOR DRAIN VALVE

Figure 10–5.—Flow diagram.

pressure gages, thermometers, flow meters, and various control and by-pass valves.

Description of Basic Flow

The three basic systems of flow—raw water, distillate, and blowdown—have separate flow cycles. The raw water to be distilled enters the unit through the strainer, where suspended particles are removed. The pump, drawing the water through the strainer, pumps the raw water through the oil cooler, flow meter, and on into the heat exchanger. A pressure gage is located in the line beyond the oil cooler. The pump by-pass line allows the liquid to be circulated about the pump when the main inlet valve is partially closed. There is another by-pass line beyond the oil cooler to carry off coolant from the pump when the main inlet valve is closed. The flow meter registers in gallons per minute (gpm) the amount of water passing through it. A stop valve in the line immediately before the heat exchanger permits the raw water to circulate through the distillate exchanger or through both the distillate and blowdown heat exchangers.

All heat exchanger sections are made up of three tubes of intra-tube design (inner and outer). Only the headers differ. Looking at the unit from the engine side, as in the flow diagram (fig. 10–5), the distillate exchanger is on the left, and the blowdown exchanger is on the right. The raw water flows through the outer tube while the distillate or blowdown flows through the inner tube. In the raw water line from the pump there is a stop valve which permits control of the raw water to the distillate exchanger. This control is necessary during warm-up, to provide maximum heat savings, and during distillate production, in order to equalize distillate and blowdown temperatures.

The raw water enters both exchangers through the top sections, passing from the outer to middle to inside tubes and then down through the header into the section below. The water continues to flow in this pattern until it is finally discharged from the outer tubes in the lowermost sections. From this point the flow passes through a vent condenser and finally empties into the evaporator. In the vent condenser, heat from noncondensable gases is transferred through the tubes to the raw water.

The level of the liquids is normally controlled by the raw water inlet valve. The level height is measured with the columnar sight glass on the side of the evaporator.

BLOWDOWN SYSTEM

The concentrated water and salt taken from the bottom head is known as the BLOWDOWN. This concentration must be removed to minimize the deposit of scale on the bottom head and evaporator tube surfaces. The blowdown is subjected to the pressure in the vapor head. After leaving the bottom head, the blowdown is pumped through a stop valve, which controls the amount of liquid through the pump, and into the heat exchanger. The flow enters the outside tube in the bottom section of the blowdown exchanger and is circulated in the same manner as the raw water (except that it is in the inner tube). After passing upward through the sections to the outside tube of the top section, the blowdown is discharged as waste. A thermometer on the front header of the top section indicates the discharge temperature.

DISTILLATE SYSTEM

The distillate, subjected to the compressor discharge pressure, flows from the bottom tube sheet into the hot well. Normally, the flow is direct to the heat exchanger. The distillate enters the outside tube of the bottom section and flows within the inner tubes to the outside tube in the top section in a pattern identical to that of the blowdown flow. A stop valve controls the distillate flow to storage. The thermometer in the outlet header registers the discharge temperature of the distillate. Some of the distillate will be required in two other locations, the engine boiler, and the compressor. The engine operates with distilled water, except for emergency starting. A liquid level control acting as an automatic valve maintains the proper level.

The compressor will require occasional flushing with the distilled water to wash away any scale which may have been deposited on the rotors. The flushing valve is manually controlled.

Operating Instructions

The most important factor in the efficient operation of any distillation unit is to maintain the proper heat balance, which is the relationship of the amount of heat used to the amount discharged from the unit. If this requirement is met, the unit will operate at maximum efficiency. This means that a minimum amount of fuel oil will be required to produce distillate and that scale formation on the heat transfer surfaces will be kept at a minimum.

There are four mechanical components which require particular care. These are the engine, the compressor, the raw water pump, and the blowdown pump. The engine and compressor, in particular, require diligent care. Follow the instructions of the operating manual carefully.

PRECAUTIONS

Observe the following precautions in operating the unit:

1. Drain the unit completely for long shutdown or when freezing may occur.
2. De-scale the unit when the difference in pressure between the evaporator gages reaches 5 psig, maximum 6 psig.
3. Do not start the engine unless the level gage on the engine boiler is full.
4. If the water foaming in the evaporator head causes a carry-over, reduce the operating level to a point where the carry-over stops.
5. If the engine boiler was filled with sea water, withdraw gradually from the drain at intervals during normal operation. The make-up valve will automatically dilute during distillate production.

PREPARING TO START

Use the following procedure to start the unit:

1. Lubricate at all points (on the model DVC–8, fittings are marked red).
2. Fill the engine and the compressor with lubricating oil to the proper level.

3. Fill the fuel oil tank.
4. Open the following valves: by-pass line valve, feed pump cooling valve (valve J), raw water inlet valve, compressor butterfly valve. The raw water pump by-pass valve should be only partially opened.
5. Close the following valves: blowdown discharge valve, vent condenser valve, heat exchanger by-pass valve, engine boiler vent valve, compressor flushing valve, heat exchanger distillate vent, heat exchanger blowdown vent, and evaporator drain valve.
6. Close all drains except the compressor base drain (which should be closed shortly after starting the compressor).
7. Check to be sure that all gage valves are open.
8. Clean both strainers and fill to top with water to prime raw water pump and suction line.
9. Remove the filling plug and fill the engine boiler to the top, using pure water if possible.
10. Check suction connections for leaks.
11. Check all sheaves and belts for tension.

WARM-UP CYCLE

Use the following procedure for the warm up:

1. Place the throttle in mid-speed position.
2. Push the reset button and the starter button, and if necessary, hold the reset button until the engine oil pressure builds up.
3. When the engine starts, watch for build-up of oil pressure within 15 to 20 seconds.
4. Engage the clutch to start the compressor.
5. Fill the evaporator until the level reaches the middle of the gage glass. Close the raw water inlet valve, maintaining the level as required. Maintain exhaust temperature of 600° F by adjusting valve *D*.
6. When the evaporator head gage reaches 0 psig, partially open the vent condenser vent valve.

7. Bring the evaporator head gage pressure up to 1 to 2 psig, then close the by-pass line valve and the feed pump cooling valve; open the blowdown discharge valve. (Distillate and blowdown production can be speeded up by using the vents on the heat exchangers.)
8. Close off the compressor butterfly valve (if additional heat is required).
9. Partially open the heat exchanger by-pass valve when the blowdown flow starts. Equalize the heat exchanger thermometer readings by means of this valve.

DISTILLATE PRODUCTION

When the distillate starts to flow, operate with 1 to 2 psig pressure in the vapor head. Maintain the normal evaporator water level by adjusting the raw water inlet valve and regulating with the raw water pump by-pass valve. The flow meter for the raw water should read about 3 gpm. The flow meter for the blowdown should read 1½ gpm. The vent condenser vent valve should normally be open about 1 to 1½ turns.

SHUTTING DOWN THE UNIT

To shut down the unit, first move the fuel control lever all the way to the stop position. For a short shutdown (five minutes or less), stop the engine, close the distillate discharge valve and the blowdown discharge valve in order to maintain the evaporator pressure. When the unit is restarted, both of these valves should be closed.

For a prolonged shutdown or where freezing is likely, drain the unit completely.

200-GALLON PER HOUR UNIT

The 200-gallon per hour distillation unit, model DVC–20, is similar to the model DVC–8 unit, but is considerably larger. Its over-all length is 114 inches, width

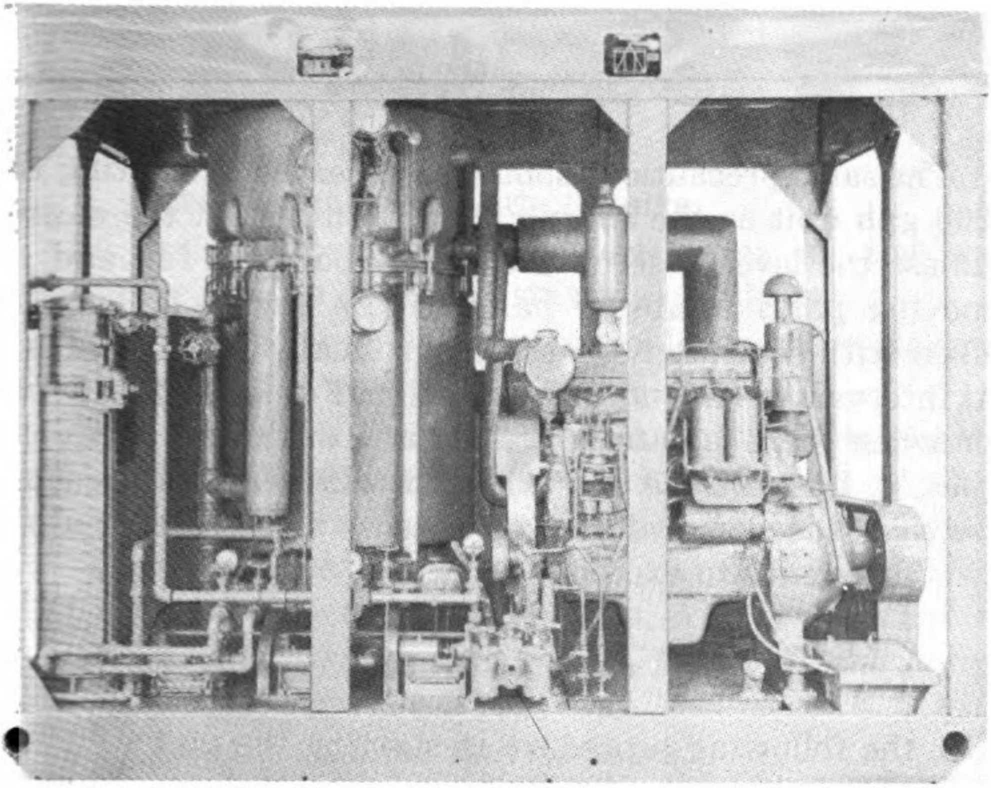


Figure 10–6.—200 gph distillation unit, Model DVC–20.

73 inches, height 90 inches, and weight 9,000 pounds. (See fig. 10–6.) Like the 85 gph unit, the 200 gph unit produces about 1 gallon of distillate for each 2 gallons of raw water.

Basic Flow

The basic flow of the 200 gph unit is similar to the 85 gph unit. The raw water enters the unit through a strainer which removes suspended particles. The water then flows to the heat exchanger and from there to the vent condenser, from which it empties into the evaporator. In the evaporator, the raw water is first vaporized and then condensed. The fluid from the evaporator is discharged in two forms: blowdown and distillate. Blowdown is discharged as waste, while the distillate is stored for use. Both the blowdown and distillate are pumped through the heat exchanger to transfer their latent heat to the raw water.

Operating Procedure

The same precautions should be observed in starting the 200 gph unit as the 85 gph unit. Do not start the engine unless the level gage on the engine boiler is full and all moving parts rotate by hand. If the engine boiler was filled with sea water, withdraw gradually from the drain at intervals during normal operation. For long shutdowns, or when there is danger of freezing, drain the unit completely. De-scale the unit when the difference in pressure between the evaporator gages reaches 5 psig. Never allow this difference to exceed 6 psig.

PREPARING TO START

Use the following procedure in starting the unit:

1. Lubricate at all points.
2. Fill the engine and the compressor with lubricating oil to the proper level.
3. Fill the fuel oil tank and the gasoline tank.
4. Open the feed water control valve, the evaporator by-pass valve, the vent condenser vent valve, and the compressor butterfly valve.
5. Close the following valves: oil cooling water discharge, heat control, distillate control, blowdown control, bottom blowdown control, evaporator drain, heat exchanger by-pass, oil cooler by-pass, and compressor flushing.
6. Close all drains except the compressor base drain, which should be closed shortly after starting the compressor.
7. Check to see that all gage valves are open.
8. Clean both strainers and fill to top with water to prime raw water pump and suction line.
9. Remove filling plug and fill engine boiler to top, using pure water if possible.
10. Check feed water suction line for leaks.
11. Check all sheaves and belts for tension.

Warm up the unit as follows:

1. Open the gasoline shut-off valve.
2. Pull the compression release lever all the way back to the gasoline (starting) position.
3. Place the engine speed control lever in the starting (shut-off) position.
4. Depress the starter button and start the engine. (The engine should be operated on the gasoline cycle about one minute; two or three minutes in cold weather.)
5. Move the compression release lever forward to diesel position and immediately advance the engine speed control lever part way.
6. Close the gasoline shut-off valve.
7. Engage the clutch to start compressor.
8. Adjust the engine speed control lever for 1350 revolutions per minute.
9. Fill the evaporator until the level reaches 10 inches in the gage glass.
10. Open the oil cooling water discharge valve.
11. Gradually close down on the evaporator by-pass valve, maintaining a constant exhaust temperature until it is fully closed.
12. Adjust the vent condenser vent valve to partially open.
13. Open the distillate control valve as soon as suction pressure approaches zero or the condenser vent begins to emit water.
14. As soon as a steady distillate flow starts, open the feed water control valve to maintain the water level, and close the oil cooling water discharge valve.
15. Open the blowdown control valve.
16. If the feed water and air temperature are unusually low, it may be necessary to close down on

the compressor butterfly valve to put more load on the engine, thus gaining more heat.

DISTILLATE PRODUCTION

If the raw water temperature is between 45° and 135° F, the unit will produce distillate within 1½ hours. When the distillate starts to flow, make the following adjustments:

1. Adjust the feed water control valve so as to hold 0.5 to 1.00 psig suction pressure, and gradually bring the flow up to 6.00 to 6.75 gallons per minute. If the lubricating oil temperature falls below 140° F, operate the oil cooler by-pass valve in conjunction with the feed water control valve to hold the temperature between 140° and 160°. Low feed water and air temperature may make it necessary to keep the compressor butterfly valve partially closed.
2. As soon as the blowdown starts, adjust the heat exchanger by-pass valve to equalize the heat exchanger thermometer readings.
3. Regulate the heat control valve to maintain 0.5 to 1.0 psig in the vapor head.
4. If the blowdown falls below normal (150 to 200 gph) because of excessive foaming or line plugging while using top overflow, supplement by taking blowdown from the bottom head.
5. Adjust the compressor flushing valve to give a reading on the Junior Flowrator of from 0.1 gpm at 3 psi differential pressure to 0.2 gpm at 5 psi differential pressure.

SHUTTING DOWN

Use the following procedure to shut down:

1. Open the gasoline shut-off valve.
2. Simultaneously pull the compression release lever to the gasoline position and move the engine speed control lever to the shut-off position.

3. Allow the engine to operate on gasoline until the exhaust is clear; then stop the engine by placing the compression release lever in the diesel position.
4. Close the feed water control valve, the heat control valve, the distillate control valve, the blowdown control valve, and the compressor flushing valve.

OPERATING TROUBLE

After the distillation unit (DVC–20 or DVC–8) is in operation, you will occasionally encounter operating problems. Operating troubles may be classified as: general, evaporator, heat exchanger, compressor, and blowdown pump. The first column of the chart below lists common operating troubles. The second column gives the probable cause or causes of the trouble.

OPERATING TROUBLE CHART

Trouble	Probable cause
GENERAL	
Surplus heat	Low water level Scaling Compressor packing too tight
Lack of heat	Too low feed water temperature Too low exhaust temperature
Too low *p*H	Improper venting of evaporator shell
Too high conductivity	Overgreasing of feed pump Overgreasing of compressor Dirty or leaky exchanger Evaporator by-pass valve not closing or seating properly
Difficulty in maintaining equal distillate-blowdown temperature	Equalizing valve out of adjustment
Low distillate production	Scale deposit on tubes Engine not at proper speed Improper venting Loss of steam through packing glands of compressor Leaks in tube sheets where they are expanded Evaporator by-pass not closing or seating properly

OPERATING TROUBLE CHART—Continued

Trouble	Probable cause
Engine failure	Low water level in engine boiler
	Low lube oil pressure
	No fuel oil
	Air in fuel lines
EVAPORATOR	
High pressure in vapor head	Excessive engine exhaust temperature
	Butterfly closed in compressor discharge duct
	Low water level in evaporator
	Scaling of evaporator
	Improper venting
	Compressor packing too tight
Low pressure in vapor head	Butterfly open too far in compressor discharge duct
	Heat exchanger temperature gages not equalized
	Engine boiler vent valve or filling plug open
	By-pass line valve open
High pressure in shell	Scale deposit on tubes
	Insufficient venting of shell through vent condenser vent valve
	Faulty gage
	Low water level (supply pump not pumping or supply tank empty; hand valve not opening properly; obstruction in valve; dirty strainers)
Low pressure in shell	Compressor operating below rated speed
	Excessive clearance between lobes in compressor
	Distillate hot well drain valve open
	Evaporator by-pass line valve open
	Faulty gage
	High water level (hand valve leaking or not closing properly)

OPERATING TROUBLE CHART—Continued

Trouble	Probable cause
High differential between head and shell pressures	Scale deposit on tubes Improper venting of air from shell Faulty gages Improper water level in tubes
Low differential between head and shell pressures	Leak in compressor seals Excessive clearance between compressor lobes Faulty gages
Failure to hold constant water level (within ½ in. variance)	Faulty level control Clogged raw liquid strainer Failure of water supply
HEAT EXCHANGER	
Salinity condition in distillate	Leak through tube surface Leak in fitting or at tube sheet Carry-over of salt particles from evaporator due to high water level
Improper temperature relationship between the distillate discharge and raw water inlet	Scale deposit on tubes
COMPRESSOR	
Excessive bearing or gear wear	Improper lubrication
Loss of compressor efficiency due to leakage of steam	Improper clearance between lobes of compressor Improper clearance between lobes and casing Improper end clearance between lobes and casing
Noise in compressor ------	Oil level too low (improper oil; insufficient or improper grease) Water passing through lobes Friction of lobes with each other on the casing or the end plates Scale formation on lobes (can be removed by flushing lobes with distilled water)
BLOWDOWN PUMP	
No water delivered ------	Discharge head too high Impeller completely clogged Plugged blowdown valve or line Solids or dirt in heat exchanger

Trouble	Probable cause
Not enough water delivered	Air leaks in suction pipe or stuffing box Leaky or plugged heat exchanger Discharge head higher than anticipated Impeller partially clogged Mechanical defects (worn or damaged impeller; worn casing)
Not enough pressure ------	Air in water Mechanical defects
Pump works for a while and then quits	Leaky suction line Water seal clogged
Pump takes too much power	Mechanical defects (bent shaft; impeller binds in casing; stuffing box packing too tight)

One of the most common operational difficulties is obtaining the proper rate of blowdown discharge. This is frequently caused by a clogged line or a pump. To check for this operating trouble, remove the hose connection between the evaporator and the blowdown pump.

MAINTENANCE AND REPAIR

Both model DVC–8 and DVC–20 distillation units require a certain amount of maintenance. The maintenance may be divided into two categories: (1) normal servicing as necessary to assure efficient operation; (2) checking of equipment at stated intervals, so that defects—if present—can be located and corrected.

Normal servicing includes cleaning, lubrication, and making simple adjustments. The diesel engine, fuel supply pump, compressor, blowdown pump, and raw water strainer are items which must be frequently cleaned or lubricated. The manual of operating instructions accompanying a distillation unit explains the type of lubricant to use, frequency of lubrication, and manner of cleaning.

Inspection is an important phase of maintenance. Some equipment, such as the fuel supply pump and boiler level control, will require inspection and cleaning only twice or three times a year. Other parts of the unit, such as the generator, require much more frequent inspection. Any part of the equipment which becomes inoperative must, of course, be examined immediately.

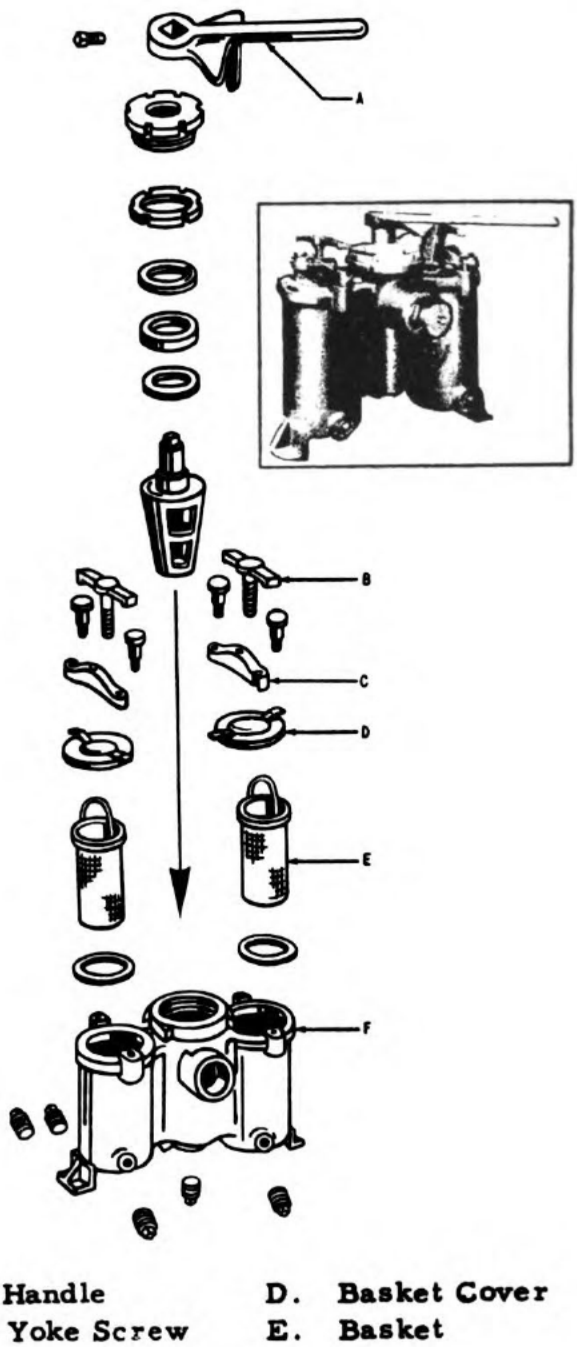
Cleaning the Water Strainer

Raw water enters the unit through the strainer shown in figure 10–7. The strainer needs no maintenance other than an occasional cleaning of the perforated baskets (*E*). The position of the handle (*A*) on the strainer indicates which basket is in use. The other basket may be removed by backing off the yoke screw and swinging the yoke clear of the basket cover. The basket is then exposed and may be removed from the body. Clean it by sloshing vigorously in clean water. Replace in the strainer body and lock in place by reversing the disassembly procedure. Set the strainer handle in the opposite position; the second basket may then be removed and cleaned.

Removing Scale Formation

Scale is formed in distillation equipment by the crystallization of certain materials found in raw water. This material is deposited on the inside of the evaporator tubes, and will reduce distillate output. Scale should be removed every 150 to 720 hours of operation, depending principally upon the amount of scale-forming components in the raw liquid.

Scale may be removed either by chemical or mechanical means. The chemical method is more common. Either hydrochloric acid or nitercake (sodium bisulfate) may be used as the chemical cleaner. The amount of chemical cleaner required will depend upon the number of hours of operation since the last cleaning or the amount of distillate produced since the last cleaning. If hydrochloric acid is the chemical, use 0.25 gallon (in a 31 percent



A. Handle
B. Yoke Screw
C. Swing Yoke
D. Basket Cover
E. Basket
F. Body

Figure 10-7.—Raw water strainer assembly.

solution by weight) for each 1000 gallons of distillate produced. If nitercake is the cleaning chemical, use 2.27 pounds for each 1000 gallons of distillate.

If you determine the amount of chemical by the number of hours of operation, figure as follows: 2 gallons of hydrochloric acid for each 100 hours for the 85 gph unit and 5 gallons for each 100 hours for the 200 gph unit. If the chemical is nitercake, use 19.3 pounds for each 100 operational hours for the 85 gph unit and 45.4 pounds for the 200 gph unit.

For the cleaning operation, you will need an acid-resisting hose, and an acid vat or large wooden tank. For the 85 gph unit, you may use a clean 50-gallon oil drum. The capacity of a vat used to clean the 200 gph unit should be at least 130 gallons. Fill the vat or drum almost to capacity with fresh water, and add acid or nitercake in the amount described above. Always add acid to the water and not water to the acid, since the latter may cause spattering.

After the cleaning mixture is prepared, place the raw water, blowdown, and distillate hose sections in the drum or vat. Start up the unit and run for about 4 hours. The acid solution will circulate through the distillation unit. You can determine the effectiveness of the cleaning by observing scale formation on the top tube sheet through the vapor head inspection window. It is good practice to check the *p*H of the solution about once an hour. If the solution becomes more than 5.0 on the *p*H scale, strengthen it by adding more acid. When the unit is clean, shut it down and drain.

Immediately after cleaning, run the unit for at least an hour under full distillate production, discharging the distillate as waste. This removes traces of the acid. Do not connect the distillate line to storage until a *p*H check shows that the distillate is neutral.

The chemical method, of course, is not practicable unless the scale is soluble in acid. Test the scale by placing a few drops of acid on it; if the scale dissolves, you may use the chemical method.

MECHANICAL METHOD

The mechanical method is usually used only when the chemical method is not practicable. This situation normally occurs when acid will not dissolve the scale or when the scale formation is excessively deep.

A drill-type tube cleaner should be used for mechanical cleaning. Water lubricated drills having carbide tips work best. Shut down the unit and remove the vapor head. Chip the scale from the upper tube sheet, and proceed to clean the tubes in accordance with the instructions accompanying the tube drill. After finishing the chipping, flush the unit thoroughly from the top with a hose to remove all loose scale. The unit is ready for operation when the head is replaced.

OTHER DISTILLATION UNITS

The Seabees sometimes use distillation units other than the two described in this chapter. An 83 gph unit and a 150 gph unit, each using a gasoline engine rather than a diesel, are used at some bases.

The principle of operation for all compression distillation units is basically the same. If you have occasion to operate a unit other than the two just described, consult the manufacturer's manual describing the machine. The type of engine and the location of the parts may be different, but the operating procedure will be much the same.

QUIZ

1. What is the ultimate product resulting from condensation called?
2. How is the heat generated to continue the compression distillation process?
3. In compression distillation, how is heat replaced which is lost through radiation and the discharge of distillate?
4. What is the maximum time which the 85 gph distillation unit should operate without cleaning?
5. What are the essential components of the 85 gph and the 200 gph distillation units?
6. Name the three basic systems of flow in the model DVC-8 and the model DVC-20 distillation units.
7. What is the concentrated water and salt solution taken from the bottom head called?
8. What is the most important factor in the operation of any distillation unit?
9. What are the two functions of the vent condenser?

0. How much raw water is necessary to produce a gallon of distillate?

1. In shutting down a distillation unit, when is complete drainage necessary?

2. Which of the two methods—chemical or mechanical—is commonly used to remove scale from the evaporator tubes?

3. When is the chemical method of scale removal not practicable?

4. What chemicals are generally used to remove scale?

5. In preparing the acid solution to remove scale, should water be added to the acid or acid to the water?

6. For operational purposes of a distillation unit, what is considered a short shutdown?

7. Into what major categories are operating troubles divided?

8. What part of the distillation unit removes particles suspended in the raw water?

9. What is the purpose of the heat exchanger?

0. If the raw water temperature is between 45° and 135° F, how long does it take a unit to start producing distillate?

CHAPTER 11

ROUTINE DUTIES IN A WATER PURIFICATION PLANT

In a typical water purification plant you will find various types of equipment. In the hands of competent personnel the equipment produces sufficient safe water to meet the needs of the area being served. As water treatment may vary from place to place, according to local water requirements, the plants with their equipment also may vary. Let's look at a typical plant.

Connected with the plant is a storage system. Reservoirs, basins, and tanks may be used to store water. This supply of water is used to meet any emergency need, and to regulate the water pressure within the system. The sun, currents, and overturns, by which the bottom water changes place with the surface water, are three methods which nature uses to purify the water. The water goes from the storage area through intake screens to the water plant.

At some water plants, plain sedimentation basins are occasionally used to permit the natural settling of solids heavier than water. However most plants use chemical coagulation which results in more rapid sedimentation.

You will find that proportioning machines, known as dry feeders, are used for the automatic feeding of soda ash, alum, and other chemicals into the water. Figure 11–1 illustrates one type of dry feeder.

Sometimes the chemicals are added in the suction line of the pumps being used. This method also allows mixing to take place.

Regardless of the method used, the mixing of the chemicals with all of the water is important to the forma-

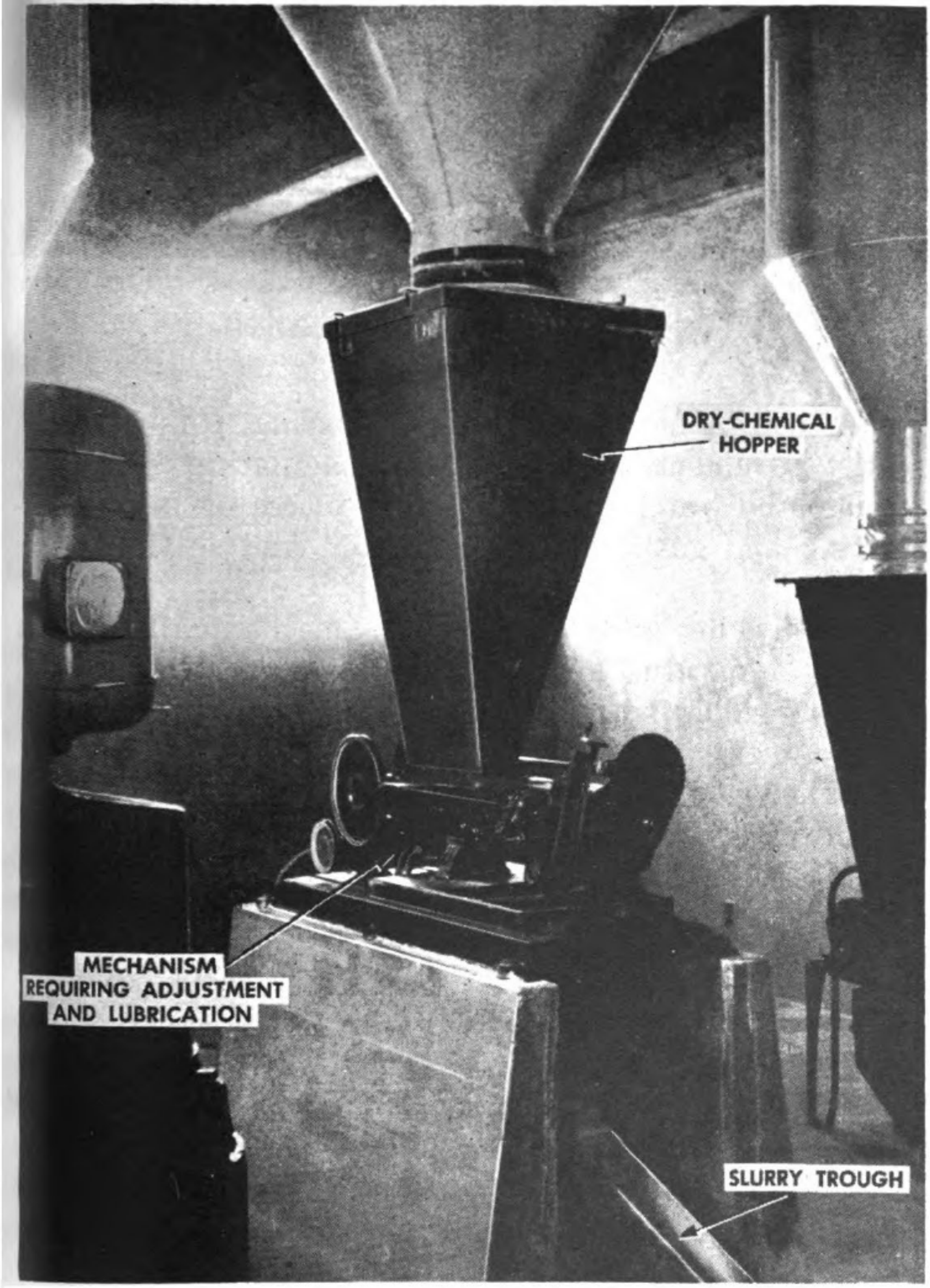


Figure 11–1.—Dry chemical feeder.

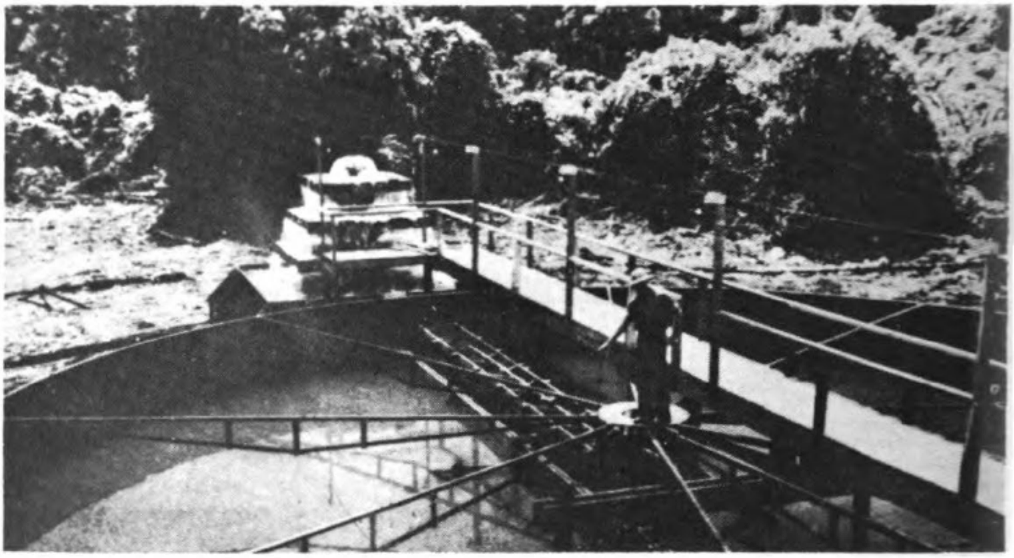
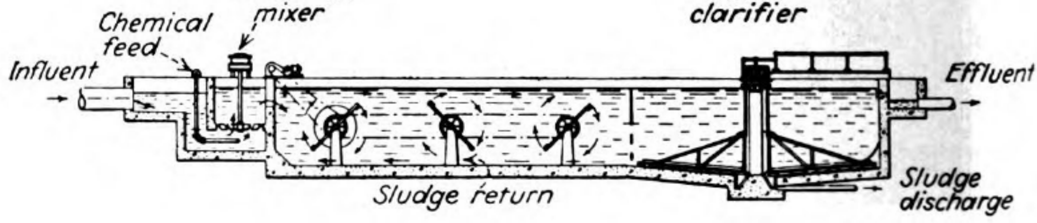


Figure 11–2.—Sedimentation tank in operation.

tion of floc. A quick agitation or stirring, followed by a gentle movement, results in the coagulating floc going through the water, forming larger pieces of matter, entangling and gathering more matter, and settling more rapidly.

Specially designed tanks with mechanically driven stirring apparatus may be used for this. Figure 11–2 shows a paddle wheel arrangement which may remind you of a merry-go-round.

Another arrangement of paddles raises the water from the bottom of the basin toward the top. These paddles are known as flocculators and produce a compact floc. They work on a ferris-wheel principle, illustrated in figure 11–3.



Courtesy of McGraw-Hill

Figure 11–3.—Mixing basin with flocculators.

The water, mixed with the chemicals and containing floc, now goes to coagulation-sedimentation basins. Here the floc settles, usually within 6 hours. Inlets are designed to let the chemically treated water in without disturbing the settling process. Outlets for the removal of the sludge that has settled are also provided. In some plants where very turbid water is treated, mechanical removal of sludge is provided by special apparatus.

The coagulation process removes some of the dirt and bacteria from the water. However, the job isn't done well enough ordinarily, and filtration is necessary. In the United States, the RAPID-SAND FILTER was developed during the period 1900–1910. It has replaced the slow-sand filter to a great extent.

There are two types of rapid-sand filters, the PRESSURE or closed type, and the GRAVITY or open type. The pressure filter (fig. 11–4) and the gravity sand filter (fig. 11–5) are alike in their essential features.

The pressure filter is enclosed in an iron or steel cylinder and uses water pressure in forcing water through it. The gravity filter, on the other hand, is usually an open structure of wood, steel, or concrete. The water flows through it by gravity.

Sand and gravel are used as the filtering medium. As the water goes through the top layers of sand it leaves the floc, mud, and other things it was carrying. In a little while this builds up a blanket or layer that helps catch other objects as they come by. An underdrain system collects the filtered water and also sprays water upward when the filter is being backwashed. The filtered water usually goes to a storage basin known as a "clear well" and then is distributed.

The filters help remove bacteria, color, tastes, odors, and mineral and dirt particles. Without filtration it would be almost impossible to produce clear and sparkling water in the quantities needed. Chlorination of the water is another process that helps the filters in obtaining water that is safe.

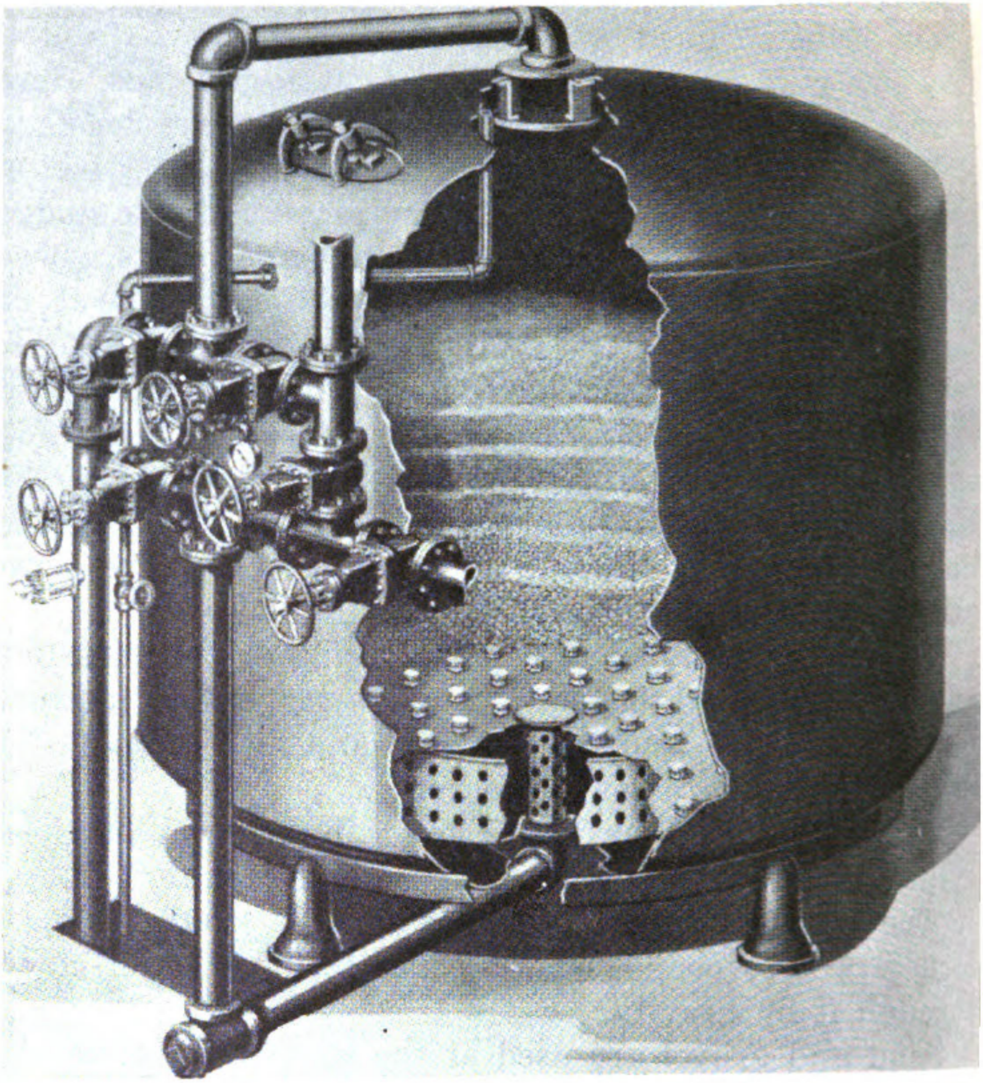


Figure 11–4.—Cross section of rapid-sand water filter, pressure type.

Some plants supply chlorine before the water goes to the filters. This prechlorination reduces the load on the filters, controls the biological growths in the basins and filters, and removes some tastes, colors, and odors.

The majority of water plants apply chlorine to the filtered water. This postchlorination process usually requires a small dose of chlorine.

Two general types of chlorination equipment have been approved for use at shore activities—chlorinators and hypochlorinators. CHLORINATORS are used for feeding chlorine gas. HYPOCHLORINATORS are used for feeding

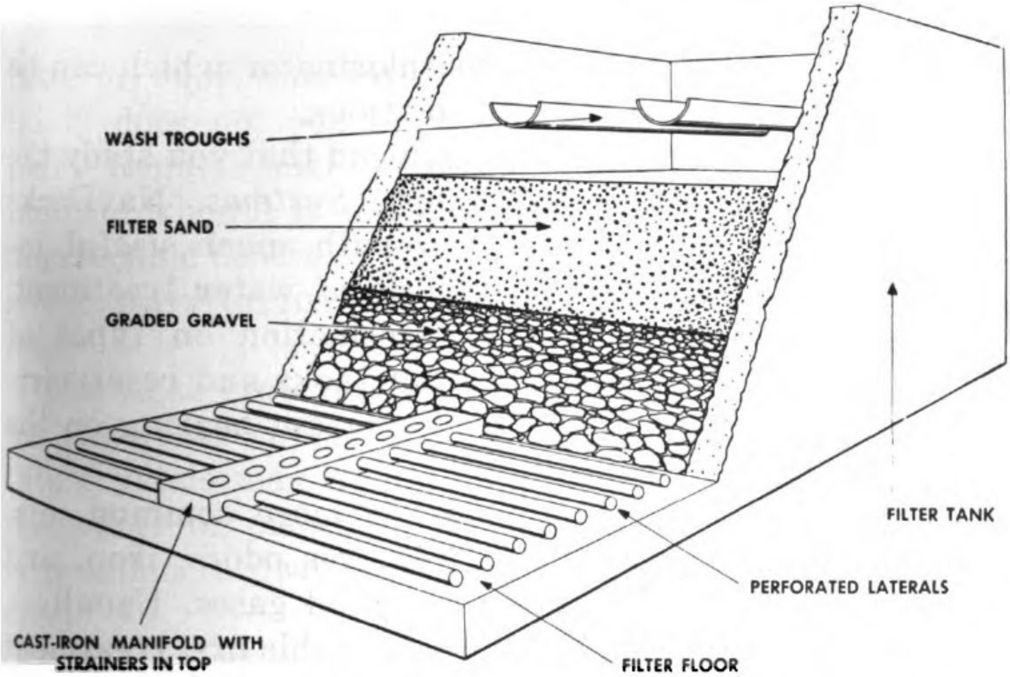


Figure 11–5.—Cross section of rapid-sand water filter, gravity type.

solutions of high-test hypochlorite or other approved chlorine compound. Other types of chlorination equipment should not be used without approval of the Bureau of Yards and Docks. Figure 11–6 shows you an auto-

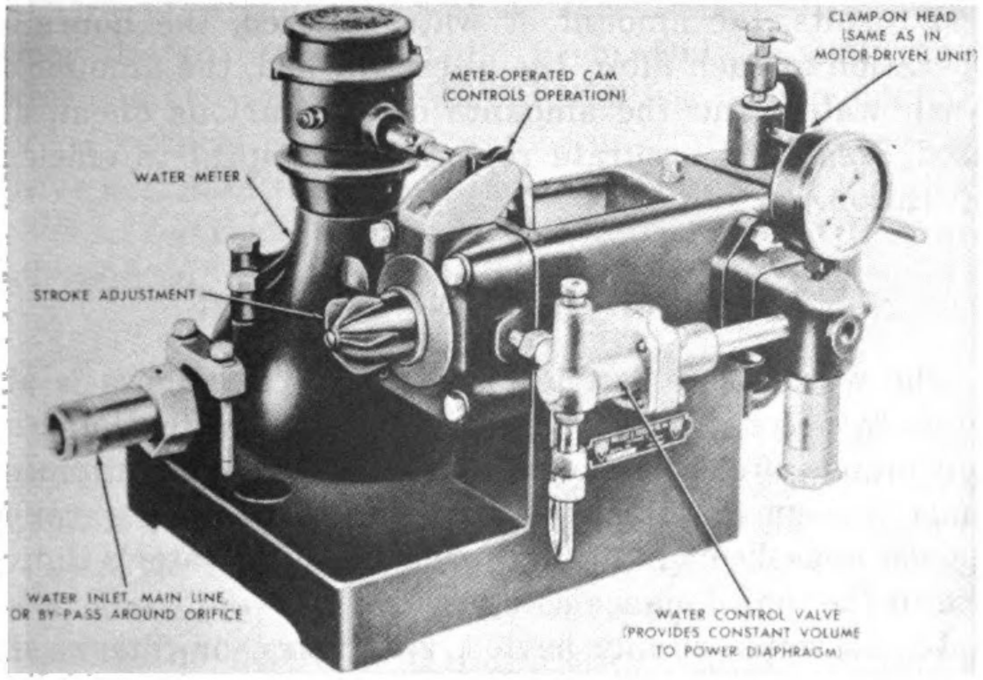

CLAMP-ON HEAD (SAME AS IN MOTOR-DRIVEN UNIT)
METER-OPERATED CAM (CONTROLS OPERATION)
WATER METER
STROKE ADJUSTMENT
WATER INLET, MAIN LINE, OR BY-PASS AROUND ORIFICE
WATER CONTROL VALVE (PROVIDES CONSTANT VOLUME TO POWER DIAPHRAGM)

Figure 11–6.—Hydraulically operated hypochlorinator, fully automatic.

matically operated type of hypochlorinator which can be used for feeding hypochlorite solutions.

Before proceeding let us recommend that you study the publication entitled *Water Supply Systems,* NavDocks TP–Pw–12. It will provide you with much useful information on conventional methods of water treatment. This reference also contains information on types of plants, the capabilities and uses of tanks and reservoirs, and other factors that have an important bearing on the water supply problem.

Aeration of water is among the more common miscellaneous water processes. It removes odors, iron, and manganese, and it also frees dissolved gases. Usually a simple cascade or waterfall is used for this first treatment before the water is mixed with chemicals.

No plant is complete without some water testing equipment. In many plants, laboratories are established. Among others, residual chlorine, color, hardness, turbidity, and bacteria tests are made regularly.

Daily records are usually kept on large monthly sheets with one line for each day. These records show the various test results, the amount of water filtered, the hours of operation of each filter, the filters washed, the amount of wash water, and the amounts of the various chemicals used. Neat and accurate reports are helpful to efficient operation.

CLEANING THE PLANT EQUIPMENT

The water plant is one place where cleanliness is absolutely necessary. That means constant attention and continuous effort. The buildings, grounds, and equipment must be kept in shipshape condition. A good operator is a good housekeeper. The majority of an operator's duties are in the maintenance category.

If the water supply basins, reservoirs, or filter walls have algae growing on them in excess amounts, you will obtain objectionable results. The water may have a bad taste or odor. The filters may clog up severely. It certainly does not add anything to the appearance of the plant. Regular microscopic examination of the water will indicate when it is necessary to take action. If there is no microscopic control, regular application of copper sulfate is necessary throughout the season when algae are growing.

The algae growth is usually prevented or kept in check by dissolving copper sulfate in the water. Copper sulfate crystals may be put in a bag and dragged through the water or placed at the inlet of the reservoir. If it is possible to drain the basins, do so and clean off the algae.

MAINTENANCE OF THE STORAGE SYSTEM

Concrete reservoirs should be inspected frequently for cracks. If you find minor cracks, patch them up with a rich cement grout mixture. If the cracks are serious, you may have to reline the whole area with a thin layer of gunnite or by alternating layers of felt and asphalt.

If the steel tanks rust or corrode, sandblast or sandpaper the surfaces and paint them. Only specially prepared paints and corrosion-preventive compounds are used. Chemical treatment may be used to reduce the corrosive action of the water. If wooden tanks are installed, check to see that their hoops are tight and that they are well painted.

MAINTENANCE OF THE BASINS

The mixing basins must also be cleaned at regular intervals. If they are operated in series, clean them in sequence, one at a time. If a septic sludge develops at the bottom of a basin, as indicated by an odor, drain and clean it at once. A fire hose and nozzle will do the job.

While the basin is drained, also inspect the valves, piping, flocculator parts, and other mechanical parts. Clean, lubricate, and replace as necessary. To clean the flocculator, spray it with a one-inch hose and a high pressure nozzle. Use enough pressure to remove the gelatinous mass sticking to the baffles. However, don't use too much pressure or you'll damage the parts.

If the basin is filled and you want to check to see if the flocculator paddles are rotating, use a bamboo or similar pole. Lower it into the water over each paddle so that the rotating paddle strikes the pole lightly. Don't use this paddle rotation check on any high speed mixers.

MAINTENANCE OF THE CHEMICAL DRY FEEDERS

The chemical dry feeders should also be inspected and cleaned regularly. Spilled chemical and chemical-dust accumulations should be removed. All parts of the feeder should be carefully wiped and checked for leaks, cracks, loose bolts, and defective parts.

Make a calibration test on the machine with the feeder on or off the scale. For a test with the feeder off the scale, you catch the chemical being delivered by the machine in a pan for a set period of time. Then weigh it and figure it in pounds per hour. Be careful in your collecting, weighing, and timing. Compare your results with the chart on the feeder. Do this several times and check the results.

For a test with the feeder on the scale, you stop the feeder and balancing scales. Then run the feeder for a set period of time. Stop the feeder and rebalance the scale. Subtract this reading from the earlier one and check the figure you get with the chart.

Lubricate the moving parts as suggested by the manufacturers. From time to time, check the chemical feeder thoroughly and clean and paint it.

MAINTENANCE OF THE FILTERS

Keeping each filter in working condition is a tough job. The filtering material must be kept clean, loose, and free of mud balls. As a filter collects the foreign matter in the water, it becomes more difficult for the water to pass through.

When the clogging has reduced the rate of flow beyond the desired rate, the filter is washed. This is done by reversing the flow of water in the same general method as described in the previous chapters.

The first step in washing a rapid-sand filter is to close the influent (inflowing water) valve and let the water drain out until the water is within 4 to 6 inches of the top of the sand. Then you close the effluent (outgoing water) valve.

Now, open the waste valve to the sewer or reclamation basin. You next gradually open the wash-water valve. This must be done very slowly so that the sand and gravel do not get mixed together by the rising water. After the top layer of the sand has been broken thoroughly you may open the valves for the maximum rate of wash. Wait for the water to appear in the sight glass before you gradually increase the rate.

Usually 4 to 6 minutes is enough time for the wash. You continue the wash until all the heavy sediment has been removed. Watching the sight glass helps you determine this. You should see some turbidity—but no heavy matter—in the water before ending the wash.

It is just as important to close the wash-water valve slowly as it is to open it slowly. This gives the sand and gravel a chance to stratify in horizontal layers, with the coarsest grains going to the bottom and the finest to the top. Such "hydraulic" grading leaves the filter bed in the best condition for filtering water.

Next, close the waste valve and slowly open the influent valve. Also open the filter-to-waste valve and, after a few minutes, close it. This filtering-to-waste is to help obtain a clear effluent. The last step in the backwash process is to open the effluent valve.

After the backwash is completed, remove the manhole plates of the pressure filter. Use a strong flashlight to examine the sand surface for dirt, cracks, mud balls, or unevenness. If the surface needs cleaning, scour it with a pressure water hose.

The gravel bed should be inspected at least once a year, or whenever sand is found in the filter effluent. This is difficult as you must first remove the sand. If necessary, replace the gravel.

When you have removed the filtering sand and gravel, inspect the filter bottom. Check each water opening in the bottom to make certain it is open. Turn on the wash water and watch the water distribution. If any pipes are clogged, clean them out. Apply a good protective paint or coating to the parts of the underdrain system which are subject to corrosion.

It is good maintenance procedure to paint the inside of the filter every time it is overhauled. Here again only specially prepared paints may be used. The exterior may be painted every year with two or three coats.

Now and then pipes will spring leaks. Therefore, they should be checked frequently. All filter valves should also be checked and operated. Where necessary, lubricate and repack any leaky valve.

In the same way as the pressure filter, the gravity rapid-sand filter must be kept free from excess dirt, hard spots, mud balls, and algae or slime. Therefore, these filters are also backwashed and sometimes are surface-washed. In addition, regular inspections and maintenance are needed.

After backwashing thoroughly in the same way as you do for the rapid-sand filter, drain the water from the filter bed. Then make a careful inspection for unevenness, sink holes, cracks, mud balls, algae, and slime.

If you find craters or holes in the sand surface, there usually will be a loose strainer cup or a break in the underdrainage joints. You'll have to find it and make the necessary repairs. If you find mud balls or cracks, surface-wash thoroughly before you backwash the filter.

If you find the sand is slime or algae covered, chlorinate heavily. Drain the filter until the water is about 6 inches deep above the sand bed. Add HTH or Perchloron until the water has 2 to 4 ppm of chlorine.

Now, open the filter-to-waste valve and draw the water level to within 1 inch of the sand. Maintain this level for about 6 hours. Then stir the surface sand thoroughly with a pressure water hose or a heavy rake. Backwash the filter. It should then be ready for normal service. With some types of algae, you may want to use copper sulphate instead of chlorine.

Periodically, the sand below the surface should be inspected. Dig carefully through the sand bed so that a cross section of the bed may be seen. Do not disturb the gravel bed. Examine the sand for mud balls and other signs of deterioration. Give special attention to the sand near the surface and at the bottom, just above the gravel.

Chemical treatment with caustic soda, sulfur dioxide, or chlorine may restore the sand satisfactorily. You may scrub the sand by washing it horizontally through a ⅛-inch mesh screen that is set on a 45° slope. If you find the sand in poor condition, replace it.

While washing the filter, check the gravel bed level. Insert a probing stick through the sand bed down to the gravel and mark the height of the water on it. Repeat this at as many points as possible. If the water-level marks are at different points on the stick, the gravel bed is uneven and needs overhauling.

From time to time, check the gravel bed condition. Shovel the sand off the top of a 2- or 3-foot-square area of gravel bed. Be careful not to shovel into or disturb the gravel. Then dig into the gravel with your bare hands to see if it is cemented, uneven, or mixed up. Do the same thing in another part of the filter. If necessary, revise the water-pretreatment, filter-washing procedures, or regrade and replace the gravel bed.

CLEANING THE AERATORS

Algae or other vegetable matter growths are frequently found in the cascade-type aerators. Scrubbing the surfaces with a long-handled brush will help remove them. Use a copper sulphate solution containing 1 lb. in 10 gallons of water. Then after the scrubbing, flush the sides with a hose stream.

CLEANING CHLORINATION EQUIPMENT

Chlorine reacts with greases, oils, ethyl alcohol, and ether to produce solid or gummy compounds that clog fittings and chlorinator parts. Therefore, chlorination equipment and piping should be cleaned only with wood alcohol or other Navy-approved cleaning agent. Make sure that adequate ventilation is always provided when a cleaning agent is used.

CHECKING THE VALVES

Regular inspection of all valves is important. The stuffing boxes must be checked for leakage and the packing must be replaced where necessary. Specific operating, lubricating, and other maintenance instructions furnished by the manufacturers of the valves are followed.

LABORATORY

To do the job right, all laboratory equipment must be operating perfectly. The measuring devices, particularly, must be accurately calibrated and the chemicals used must be pure. Keeping the laboratory clean is also a fundamental requirement in good water plant operation.

The various tests are made as required because of the local water conditions and as determined by the officials in charge. You may perform the *p*H and chlorine-residual tests as described in chapter 8. These and other tests help produce water that is safe and pleasant to drink.

QUIZ

1. What is the name of the machine that automatically feeds powdered chemicals, such as alum, into the water?
2. What type of stirring is best when coagulating chemicals are mixed with the water?
3. What is the name of the type of mixing paddle that operates on a ferris-wheel principle?
4. What is the usual settling period in the coagulation-sedimentation basins?
5. What are the two types of rapid-sand filters?
6. What process besides filtration helps produce safe water?
7. What chemical is usually used to check algae growths?
8. How long do you usually backwash a filter?
9. What kind of mixture is suitable for patching small cracks in concrete reservoirs?
0. In what way is the coagulation process beneficial?
1. What type of chlorination equipment is used for feeding solutions of high-test hypochlorite or other approved chlorine compound?
2. Name one cleaning agent suitable for cleaning chlorination equipment and piping.

CHAPTER 12

STEAM BOILERS

A BOILER is a closed vessel in which steam is generated as a result of the combustion of fuel.

A central heating plant usually has one or more boilers which utilize gas, oil, or coal as fuel. The steam or high-temperature water generated is used to supply heat to buildings and to provide hot water and steam for cleaning, sterilizing, cooking, and laundering operations. Small heating boilers play an important part in steam production, frequently being used to provide steam and hot water for small buildings. Small units can be used, also, to supply the steam needed to operate mobile emergency power equipment.

A careful study of this chapter will help you acquire a useful knowledge of steam generation, types of boilers pertinent to Seabee operations, various accessories and fittings commonly found on boilers, and so on. The object is to help you lay the foundation on which to develop skill in the operation and maintenance of boilers. Therefore, make sure you are familiar with the topics covered here before proceeding to Chapter 13, Operation and Maintenance of Steam Boilers.

STEAM OPERATION

To acquaint you with some of the fundamentals underlying the process of steam operation, suppose that you set an open pan of water on the stove and turn on the heat. You will find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212° F, or 100° C, at sea level) a physical change occurs in the water; the water starts vaporizing into steam. If you hold the temperature at boiling point long enough, the water will continue to vaporize until the pan is dry. Now a point to remember is: THE TEMPERATURE OF WATER WILL NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water will not get any hotter, as long as it remains at the same pressure.

But suppose you place a close-fitting lid on the pan of boiling water. The lid prevents the steam escaping from the pan, and this results in a buildup of pressure inside the container. However, if a small opening is made in the lid, steam will escape at a uniform rate. As long as any water remains in the vessel, and as long as the pressure remains constant, the temperature of the water and steam will remain constant and equal.

The steam boiler operates on the same basic principle as the closed container of boiling water. By way of comparison, it is true with the boiler as with the closed container, that steam formed in boiling tends to push against the water and sides of the vessel. Because of this downward pressure on the surface of the water, a temperature IN EXCESS of 212° F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat. Bear in mind, therefore, that: AN INCREASE IN PRESSURE MEANS AN INCREASE IN BOILING POINT TEMPERATURE.

There are a number of technical terms used in connection with steam generation. Here are some of the commonly used terms you should know.

DEGREE is defined as a measure of heat intensity. TEMPERATURE may be defined as a measure in degrees of sensible heat. The term SENSIBLE HEAT refers to heat that can be measured with a thermometer.

Technically speaking, HEAT is a form of energy which is measured in units known as British thermal units (Btu's). One Btu is the amount of heat required to raise 1 pound of water 1° Fahrenheit at sea level.

SATURATED STEAM refers to dry steam containing no moisture and which has not been superheated. This is almost a theoretical state as practically all steam, if not superheated, contains some moisture or wet steam.

The QUALITY of steam is expressed in terms of percent. For instance, if a quantity of wet steam consists of 90 percent steam and 10 percent moisture, the QUALITY of the mixture is 90 percent.

You know, of course, that all the water in a vessel, if held at boiling point long enough, will change into steam. What you may not know, is that there is a definite relationship between the pressure and temperature. AS LONG AS THE PRESSURE IS HELD CONSTANT, THE TEMPERATURE OF THE STEAM AND BOILING WATER WILL REMAIN THE SAME.

SUPERHEATED STEAM is steam which has been heated above the saturation temperature. For example, a boiler may operate at 415 psig (pound per square inch, gage). The corresponding saturation temperature for this pressure is 445° F and this will be the temperature of the water in the boiler and the steam in the drum. This steam can be passed through a superheater where the pressure will remain about the same but the temperature will be increased to some higher figure.

REQUIREMENTS

It is essential that a boiler meet certain requirements before it is considered satisfactory for operation. Three important requirements are that the boiler (1) be safe to operate; (2) be able to generate steam at the desired rate and pressure; and (3) be economical to operate.

Make it a point to familiarize yourself with the boiler Code and other requirements applicable to the area in which you are located.

Here are a few rules set up by ASME (American Society of Mechanical Engineers). These show the general guide lines used by engineers when designing boilers you will use.

For economy of operation, and to generate steam at the desired rate and pressure, a boiler must have:

ADEQUATE water and steam capacity
RAPID and positive water circulation
LARGE steam disengaging surface
HEATING surfaces which are easy to clean on both water and gas sides
PARTS accessible for inspection
CORRECT amount and proper arrangement of heating surface
FIRE box for efficient combustion of fuel.

TYPES OF BOILERS

In this text we are concerned, primarily, with the FIRE-TUBE type of boiler, since it is the type generally used in Seabee operations. We are interested, secondarily, in the WATER-TUBE type of boiler, which may occasionally be found in use at some activities. Water-tube boilers are so seldom used by the Seabees that the discussion herein mainly concerns the different designs and construction features of fire-tube boilers.

The basis of identifying the two types is as follows:

WATER-TUBE BOILERS are those in which the products of combustion surround the tubes and the water flows through them.

FIRE-TUBE BOILERS are those in which the products of combustion pass through the tubes and the water surrounds them.

Fire-Tube Boilers

The SCOTCH MARINE design of fire-tube boiler is especially suited to Seabee needs. (See fig. 12–1.) A portable unit, it can be moved with ease and with a minimum of

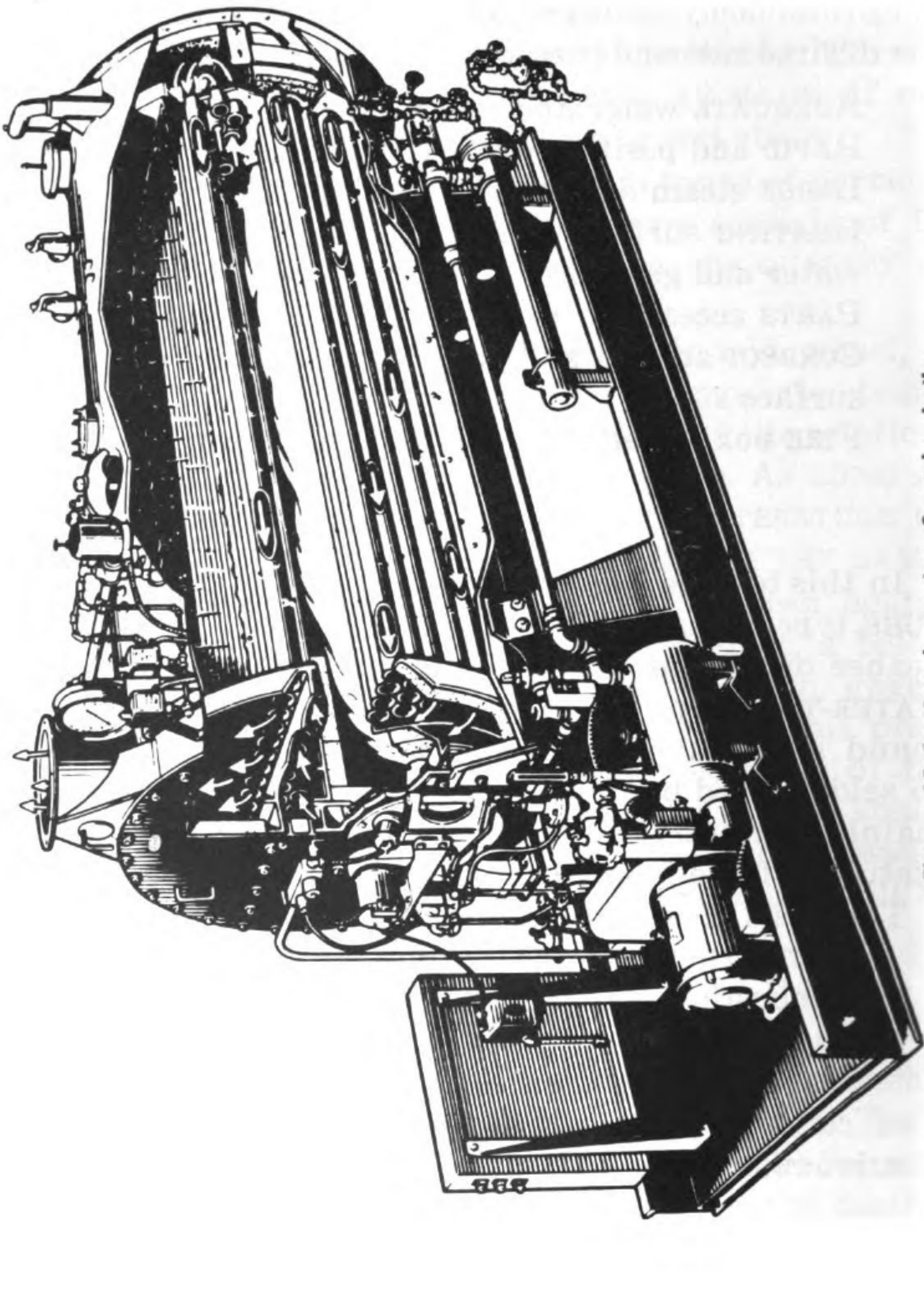


Figure 12–1.—Scotch marine fire-tube boiler.

foundation work. As a complete self-contained unit its design includes automatic controls, steel boiler, and burner equipment. These features are a big advantage because no disassembly is required when you have to take the boiler to the field for emergency work, or have to move it to a more suitable location in the area.

The Scotch boiler has a 2-pass arrangement of tubes which run horizontally. This allows the heat inside the tubes to travel back and forth. It also has an internally fired furnace, with a cylindrical combustion chamber. Its corrugated, sheet-metal firebox makes suitable provision for expansion. There is also a flue gas outlet, or smoke breeching, located on the front end of the boiler. Oil is the fuel commonly used to fire the Scotch boiler. Where desirable, though, it can be fired by gas, coal, or wood.

One advantage that the Scotch boiler has over the water-tube boiler is that it requires less space, and can be set up in a low-ceiling room. Then, too, its tubes being all the same size saves time and trouble in making tube replacements.

The Scotch boiler also has a few disadvantages. Its shell runs from 6 to 8 feet in diameter, a detail of construction which makes a large amount of reinforcing necessary. Too, the fixed dimensions of its internal furnace cause some difficulty in cleaning the surfaces of the section below the combustion chamber. Another drawback is encountered in the limited capacity and pressure of the Scotch boiler.

The SETTING of the Scotch marine boiler is self-supporting. The shell rests in two or more cast-iron cradles, and the boiler pitches 1 to 2 inches toward the rear. The setting includes a blow-down pipe which is connected to the bottom of the shell which, in turn, is screwed into a pad riveted to the shell.

The flow of gases in the Scotch boiler is toward the rear of the combustion chamber, then return by way of the tubes to the front, and out into the smoke box and stack breeching.

An important safety device is the fusible plug, which is used to provide added protection against low water. In case of low water, the plug raises a danger signal as steam escapes, giving out a loud noise. On the Scotch boiler, the fusible plug usually is located in the crown sheet, but sometimes it is found in the upper back of the combustion chamber. (Types of fusible plugs will be discussed later in this chapter.)

Aids to cleaning and repair of the boiler are provided through a manhole in the top of the boiler shell, and a handhole in the water leg. The MANHOLE is an opening which is large enough for a man to enter the boiler shell for inspection and cleaning purposes. On such occasions, always make sure all valves are secured, locked, and tagged, and that the man in charge knows you are in there. Also, have a man stationed at the outside entrance to aid and assist. The HANDHOLE is an opening large enough to permit hand entry for cleaning, inspection, and repairs to headers and tubes.

Vertical-Tube Boiler

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement of tubes in the Scotch boiler. The VERTICAL-TUBE boiler sits in an upright position. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack.

The vertical fire-tube boiler is similar to the horizontal boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholes are also provided for cleaning and repair purposes. Though self-supporting in its setting (no brickwork or foundation being necessary) it MUST be level. The vertical-tube boiler has the disadvantage of a limited capacity and furnace volume as does the horizontal-tube design.

A main factor that must be considered before selecting a vertical-tube boiler is the mount of overhead space in buildings where it will be used. Since it sits in an upright position, a room with a high ceiling is necessary to its installation.

The blow-down pipe of the vertical-tube boiler is attached to the lowest part of the water leg, and the feedwater inlet opens through the top of the shell. The boiler's fusible plug may be installed either (1) in the bottom tube sheet or crown sheet; or (2) on the outside row of tubes, one-third the height of the tube from the bottom.

Horizontal Return Tubular Boiler

In addition to operating portable boilers such as the Scotch marine and vertical-tube boiler, the UT also must be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler, illustrated in figure 12–2.

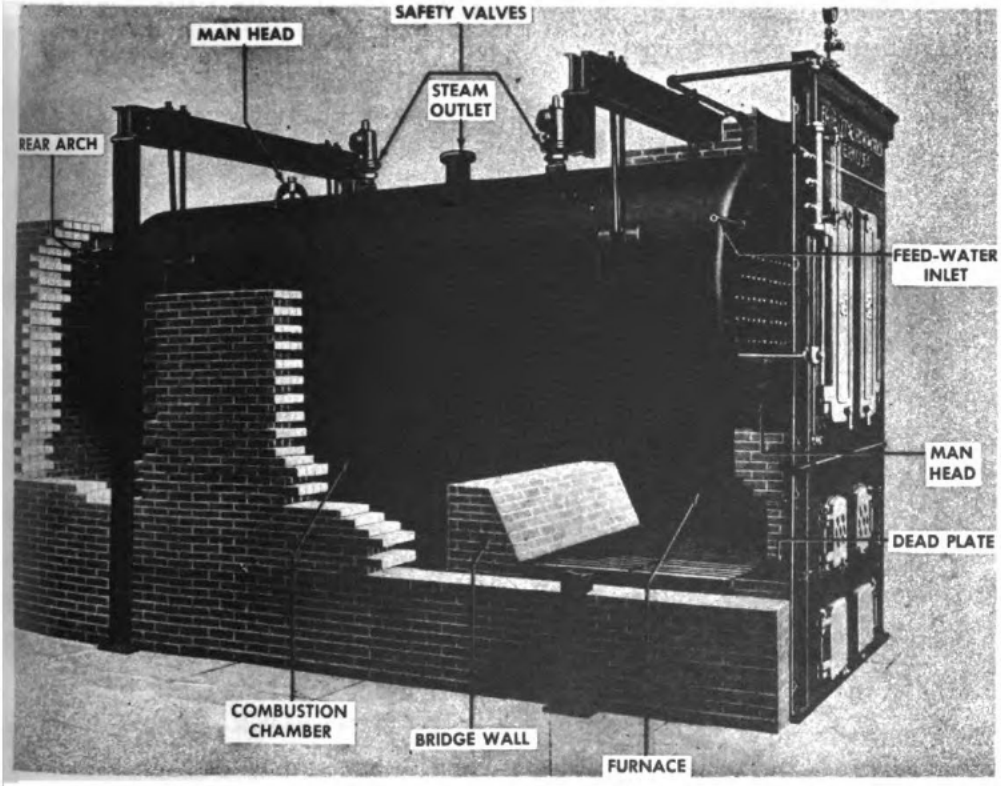


Figure 12–2.—HRT boiler.

The initial cost of the HRT boiler is relatively low, and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flow in the HRT boiler is from the firebox to the rear of the boiler, then return through the tubes to the front where it is discharged to the breeching and stack.

The HRT boiler has a pitch of 1 to 2 inches to the rear. This allows sediment to settle toward the rear. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upper part of the shell. Those over 48 inches in diameter must have a manhole in the lower, as well as in the upper part of the shell. Don't fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will be a great help to you, both NOW and LATER, in the performance of UT duties involving boilers.

WATER-TUBE BOILERS

Water-tube boilers may be classified in a number of ways. For our purpose, though, let us classify them as straight-tube and bent-tube. These two classes will be discussed separately in succeeding sections. To avoid confusion, make sure you study carefully each illustration referred to throughout the discussion.

Straight-Tube

The STRAIGHT-TUBE category of water-tube boilers includes three types: sectional-header cross drum, box-header cross drum, and box-header longitudinal drum.

Figure 12–3 shows a SECTIONAL-HEADER CROSS DRUM boiler with vertical headers. HEADERS are steel boxes into which the tubes are rolled. Feed water enters the drum

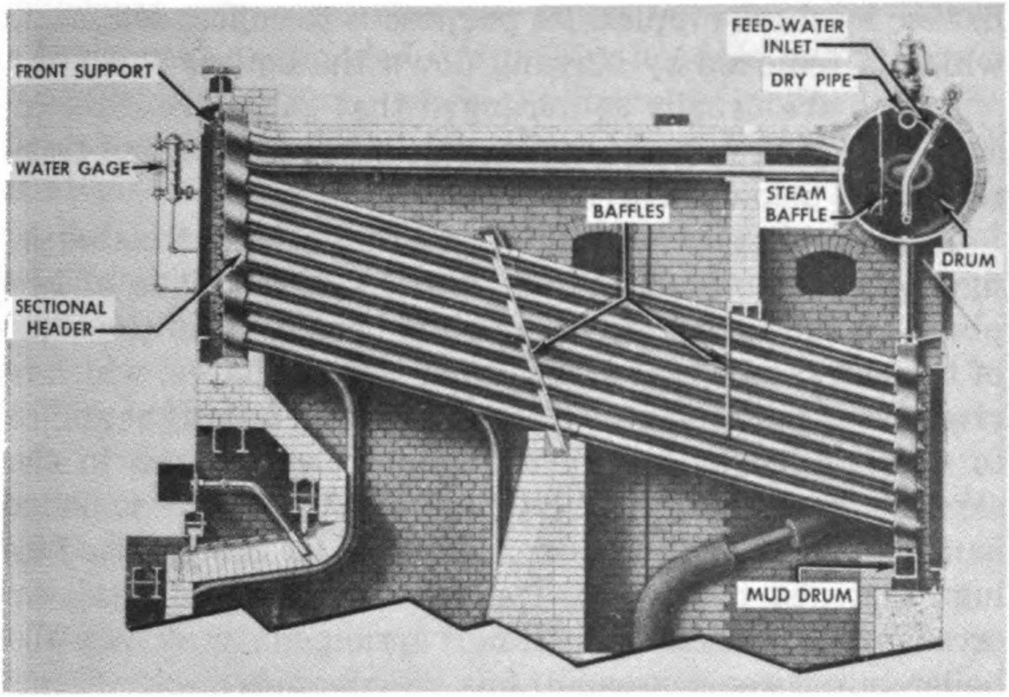


Figure 12–3.—Sectional-header cross drum boiler.

and passes down through the down commers (pipes) into the rear sectional headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle which helps to separate the water and steam.

Steam is removed from the top of the drum through the dry pipe. This pipe extends along the length of the drum, and has holes or slots in the top half for steam to enter.

Headers, the distinguishing feature of this boiler, are usually of forged steel and are connected to the drums with tubes. Headers may be vertical (as in fig. 12–3) or at right angles to the tubes. The tubes are rolled and flared into the header. A handhole is located opposite the ends of each tube; these facilitate inspection and cleaning. A mud drum is connected to the bottom of each rear header by short nipples. Its purpose is to collect sediment, which is removed by blowing down the boiler.

Baffles are usually so arranged that gases are directed across the tubes three times before being discharged from the boiler below the drum.

The **BOX-HEADER CROSS DRUM BOILER** is illustrated in figure 12–4. Box-headers are shallow boxes made of two plates: a tube-sheet plate, which is bent to form the sides of the box; and a plate containing the handholes, which is riveted to the tube-sheet plate. Tubes enter at right angles to the box-header and are expanded and flared in the same manner as in the sectional-header boiler. The boiler is usually built with the drum in front. It is supported by lugs fastened to the box-headers. This boiler has either cross or longitudinal baffling, arranged to divide the boiler into three passes.

Water enters the bottom of the drum, flows through connecting tubes to the box-header, through the tubes to the rear box-header, and back to the drum.

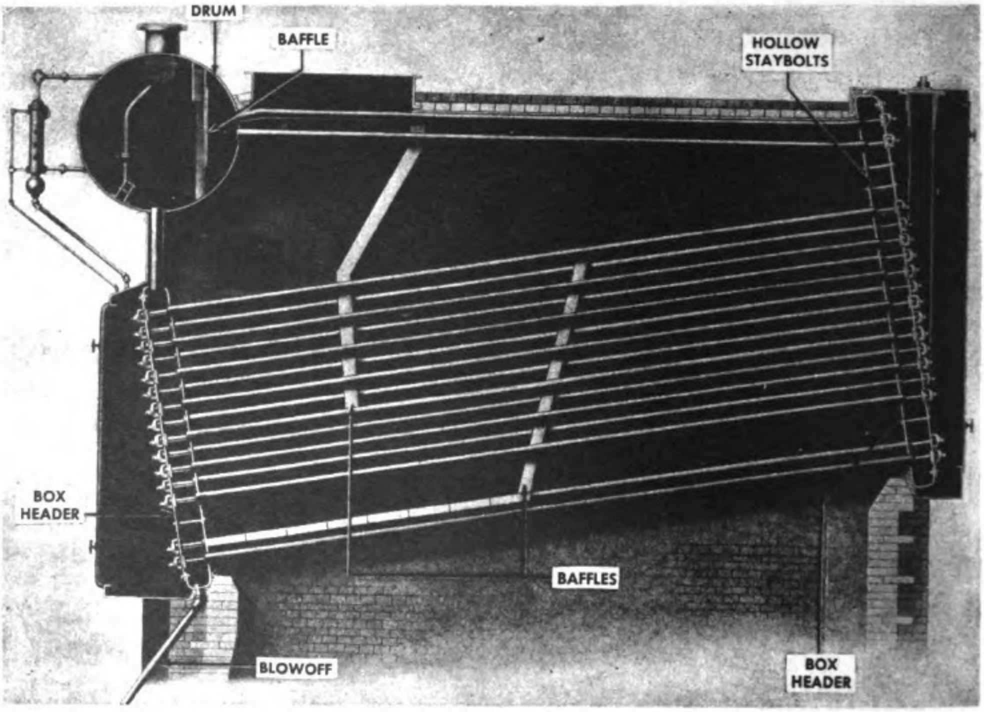


Figure 12–4.—Box-header cross drum boiler.

BOX-HEADER LONGITUDINAL DRUM BOILERS have either a horizontal or inclined drum. Box-headers are fastened directly to the drum, when the drum is inclined. If the drum is horizontal, the front box-header is connected to it at an angle greater than 90 degrees. The rear box-header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

Bent-Tube

Figure 12–5 illustrates one of the many types of bent-tube (water-tube) boilers. Boilers of this type usually have three drums, each the same in diameter but not all set on the same level. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum; steam returns to the top rear drum through the upper row of tubes while water travels through tubes in the lower rows. Steam is removed near the top of the rear drum by tubes extending across the drum, and enters a small collecting header above the front drum.

Many types of baffle arrangement are used with bent-tube boilers. Usually, they are installed so that 70 to 80 percent of the heat will be absorbed by the inclined tubes between the lower and upper front drums.

The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity, which ranges from 100,000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, but also can be modified easily for firing by oil or coal. Still another advantage is afforded by the minimum difficulty encountered in getting to sections inside the furnace for cleaning and repair purposes.

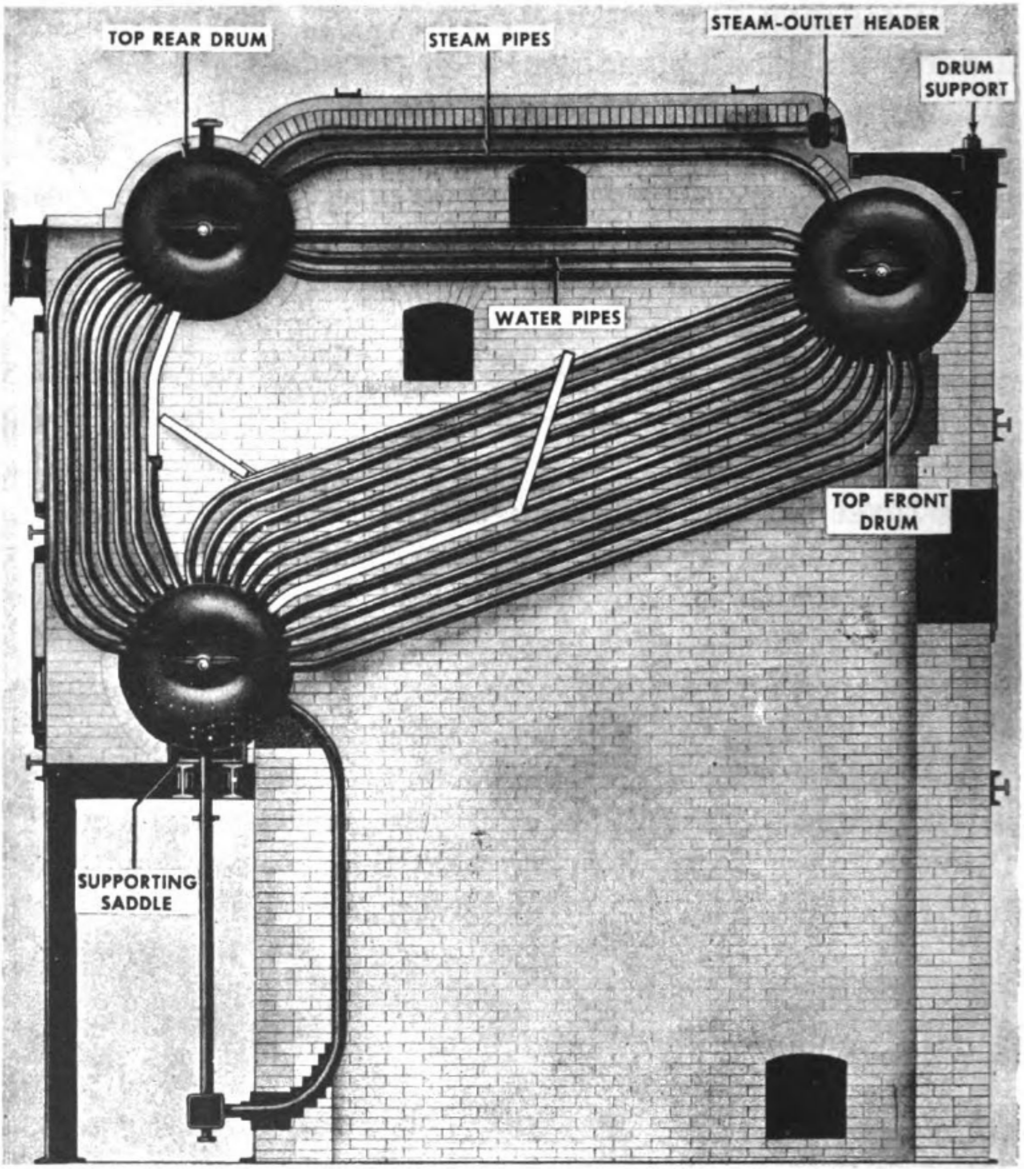


Figure 12–5.—Bent-tube boiler.

Now let us look at the other side of the picture which shows several disadvantages common to water-tube boilers. Here it can be pointed out that a high construction cost is involved, a factor which poses one of the main drawbacks to use of water-tube boilers. The large assortment of tubes required of this boiler, and the excessive weight per unit weight of steam generated, are other unfavorable factors.

BOILER PARTS AND FITTINGS

By now you should have a general idea of the overall basic structure of a boiler. A number of questions probably have come to mind as to the importance of certain boiler parts and the operation or function of various devices, such as controls, valves, try-cocks, and the like. That brings us to the topic of PARTS AND FITTINGS. A sufficient number of essential boiler parts and fittings will be discussed to provide a background for further study. As a reminder, and in case you should run across some unit or device not covered in this text, check the manufacturer's manual for information on details of construction and method of operation.

The term FITTINGS includes various controlling devices on the boiler. Bear in mind, therefore, that fittings are vitally important to economy of operation and safety of personnel and equipment. A thorough knowledge of fittings is necessary if you are to acquire skill in the installation, operation, and servicing of steam boilers.

Settings

The SETTING is the structure that encloses the boiler and forms the furnace. It may also support all or part of the boiler. The self-supported type of setting is common. The outer wall is built of hard-burned brick. The inner wall is built of firebrick to withstand high temperatures. Several examples of this type of setting are pictured in figure 12–6.

The setting of the furnace should be lined with a suitable refractory. Fire brick, fire clay, and plastic refractory are commonly used for this purpose. To select the proper refractory material, such factors as temperature, kind of fuel, method of firing, ash in the fuel, and size of the setting to be lined should be given careful consideration.

Chimneys and Breechings

Chimneys are necessary for discharging the products of combustion at an elevation high enough to comply with

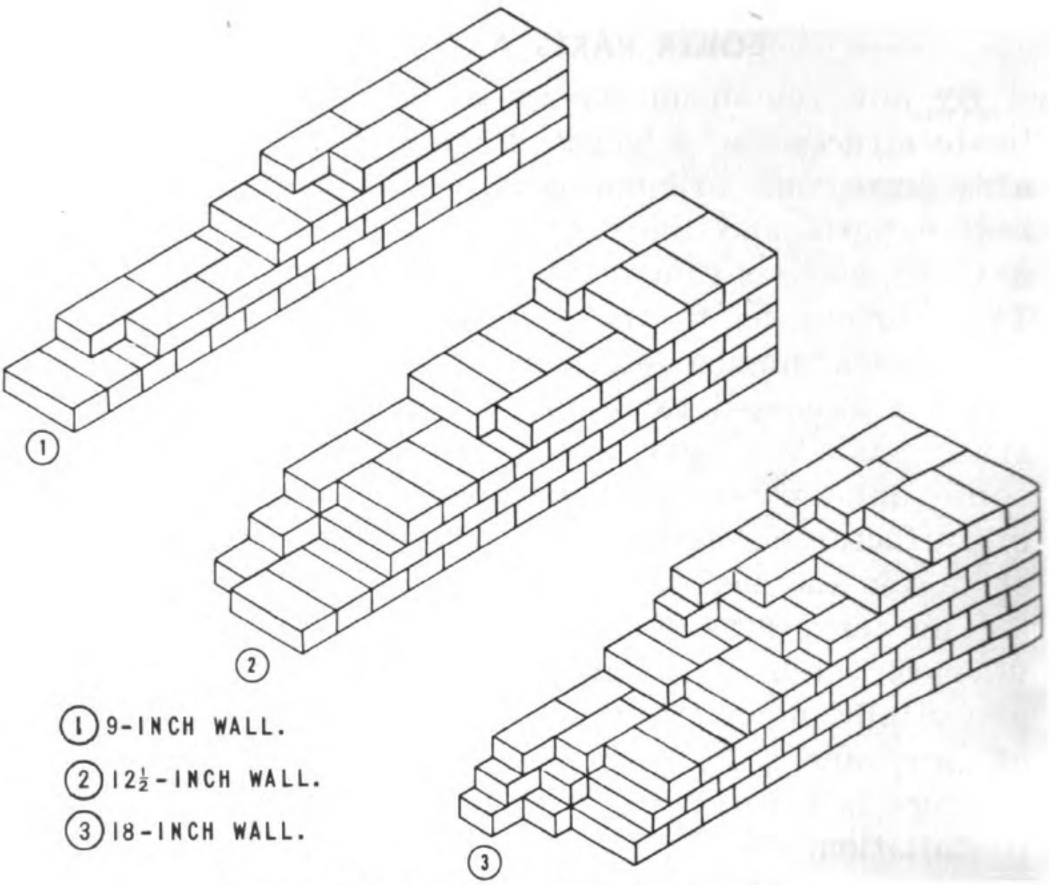


Figure 12-6.—Furnace sidewall construction.

health requirements, and to prevent nuisance due to low-flying smoke, soot, and ash. A boiler needs draft to mix air correctly with the fuel supply, and to conduct the flue gases through the complete setting. The height of the stack necessary to meet the first requirement is often enough to produce the draft necessary to meet the second.

Breechings are used to connect the boiler to the stack. They are usually made of sheet steel, with provision for expansion and contraction. The breeching may be carried over the boilers, in back of the setting, or even under the boiler-room floor.

Draft Fans

The air necessary for combustion of fuel can not be supplied normally by natural draft. Therefore, draft fans may be used to ensure that the air requirements are properly met. Two types of draft fans used on boilers are forced-draft and induced-draft fans. They are damper-controlled and usually are driven by an electric motor.

The FORCED-DRAFT fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The INDUCED-DRAFT fan draws gases through the setting, thus facilitating their removal through the stack.

Gage Glass, Water Column, and Pressure Gage

Each boiler must have at least one WATER-GAGE GLASS; if operating pressure is 400 psi (pounds per square inch) or more, two gage glasses must be provided. The gage glass allows you to tell by sight the water level in the steam drum. Water gages are so located that the middle of the glass is at the normal water level of the boiler. The gage glass must be blown down at intervals of not longer than 1 hour while the boiler is steaming.

The water-gage glasses shown in figure 12–7 are de-

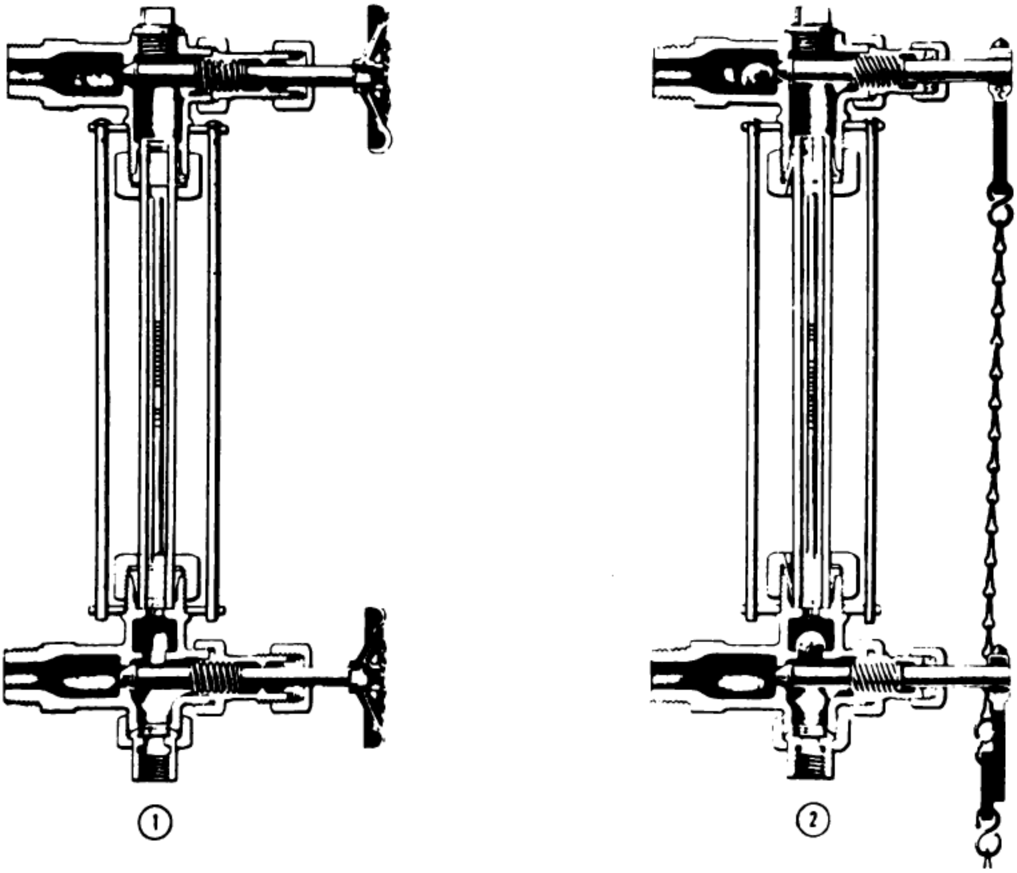


Figure 12–7.—Typical water-gage glasses.

signed for boilers which operate at low and medium pressures. Each consists of a strong glass tube connected to the boiler or water column by two special fittings. These fittings sometimes have an automatic shutoff device, usually a nonferrous ball that functions if the water glass fails.

Unless two gage glasses are installed on the same horizontal line, each boiler must have three or more gages or try-cocks (see fig. 12–8) located within the visible length of the gage glass. Gage cocks are used to check the accuracy of the gage glass. They are opened by a handwheel, chain wheel, or lever. They can be closed by hand, or by a weight or spring.

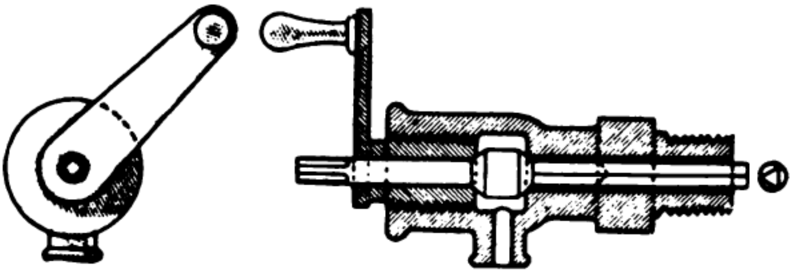


Figure 12–8.—Try-cock.

A WATER COLUMN is a hollow vessel having two connections to the boiler (see fig. 12–9). The top connection enters the steam space of the boiler through the top of the shell or head. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gage glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction of small diameter, gage-glass connections by serving as a sediment chamber.

The water columns illustrated are equipped with high- and low-water alarms which sound a whistle to warn the operator. The whistle is operated by either the two floats or the solid weights shown in figure 12–9.

Each boiler is equipped with a PRESSURE GAGE, which serves as a means of measuring pressure. There are

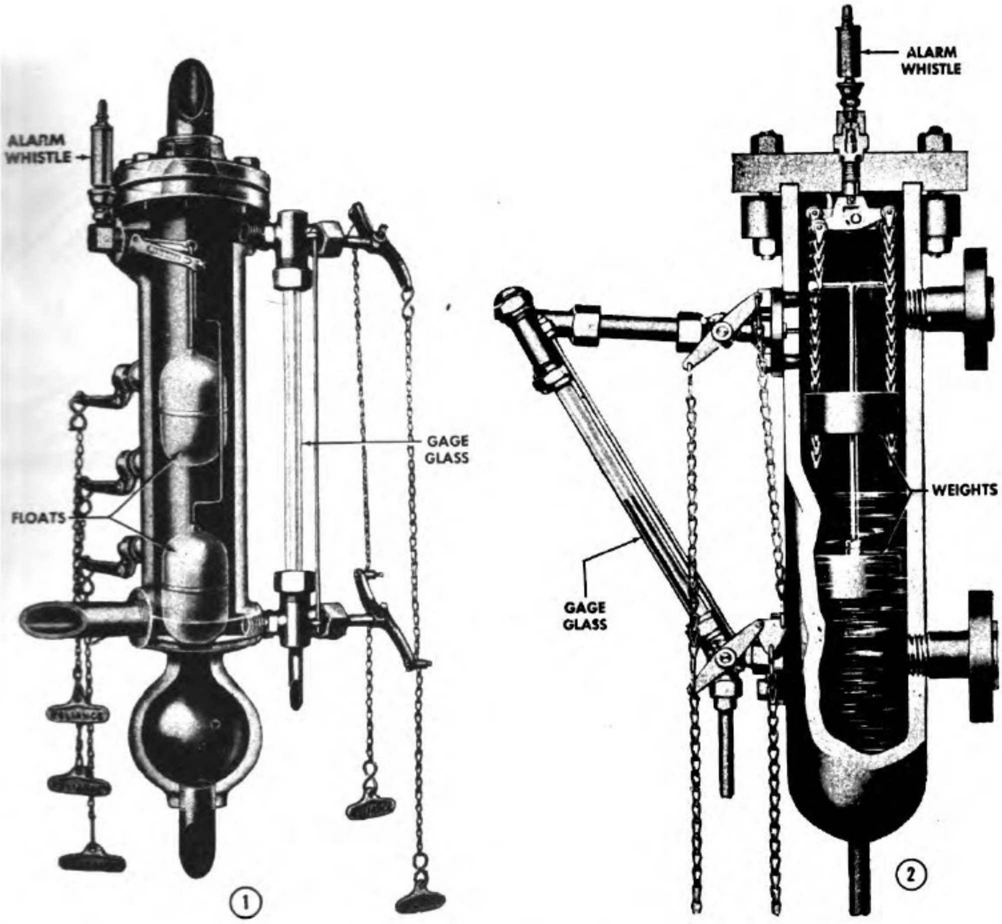


Figure 12–9.—Typical water columns.

several types of pressure gages in common use, including the Bourdon-tube gage pictured in figure 12–10.

The actuating element of the Bourdon-tube gage is oval in cross section, and is bent into an arc which is closed at one end and connected to the source of pressure at the other. When pressure within the tube rises, the cross section tends to become circular and causes the tube to straighten.

Feed-Water Regulator

An automatic FEED-WATER REGULATOR serves a very useful purpose in providing a means of automatic control of the water level in the boiler. It is designed to feed the boiler in an emergency and to ensure the smoothest possible operation.

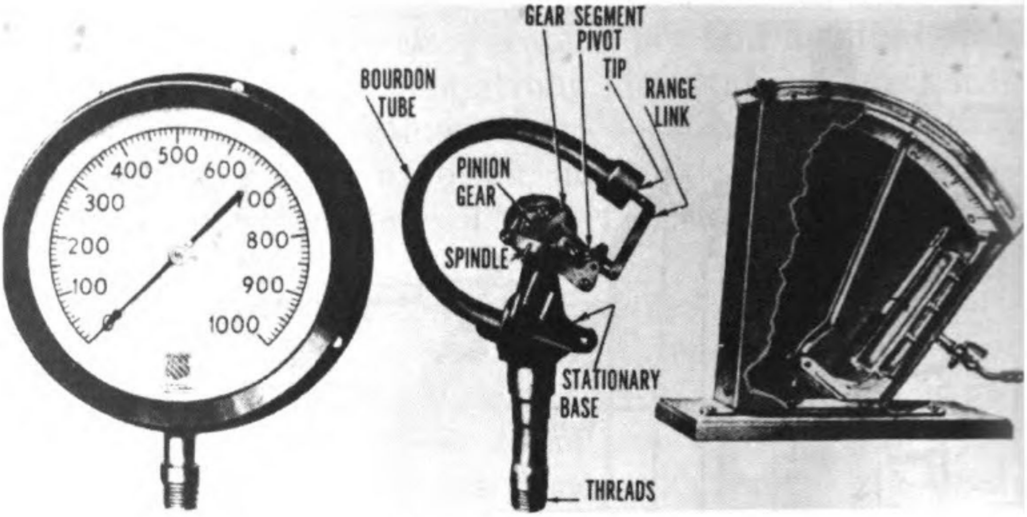


Figure 12–10.—Bourdon-tube gage.

The THERMOHYDRAULIC type of feed-water regulator (see fig. 12–11) consists essentially of a generator and a feed-water regulating valve. The generator has an outer tube with fins for cooling. An inner tube is connected to the boiler drum, with one end entering the steam space, and the other end entering the water space. The inner tube, containing steam and water, is subjected to boiler pressure so that the water level in the generator is the same as in the boiler drum.

The outer tube connecting the metal bellows of the regulating valve with copper tubing forms a closed system. The bellows is contracted and the closed system filled with water to the level of the generator filling plug before steam is turned into the generator. When the regulator is placed in operation, heat from the steam in the upper part of the inner tube causes the surrounding water to flush into steam.

The steam formed in the closed system expands and forces some of the water into the metal bellows, which expands and opens the valve. As the steam demand increases, more steam occupies the upper space of the closed system, thus opening the regulating valve a corresponding amount. Actually, the regulating valve oper-

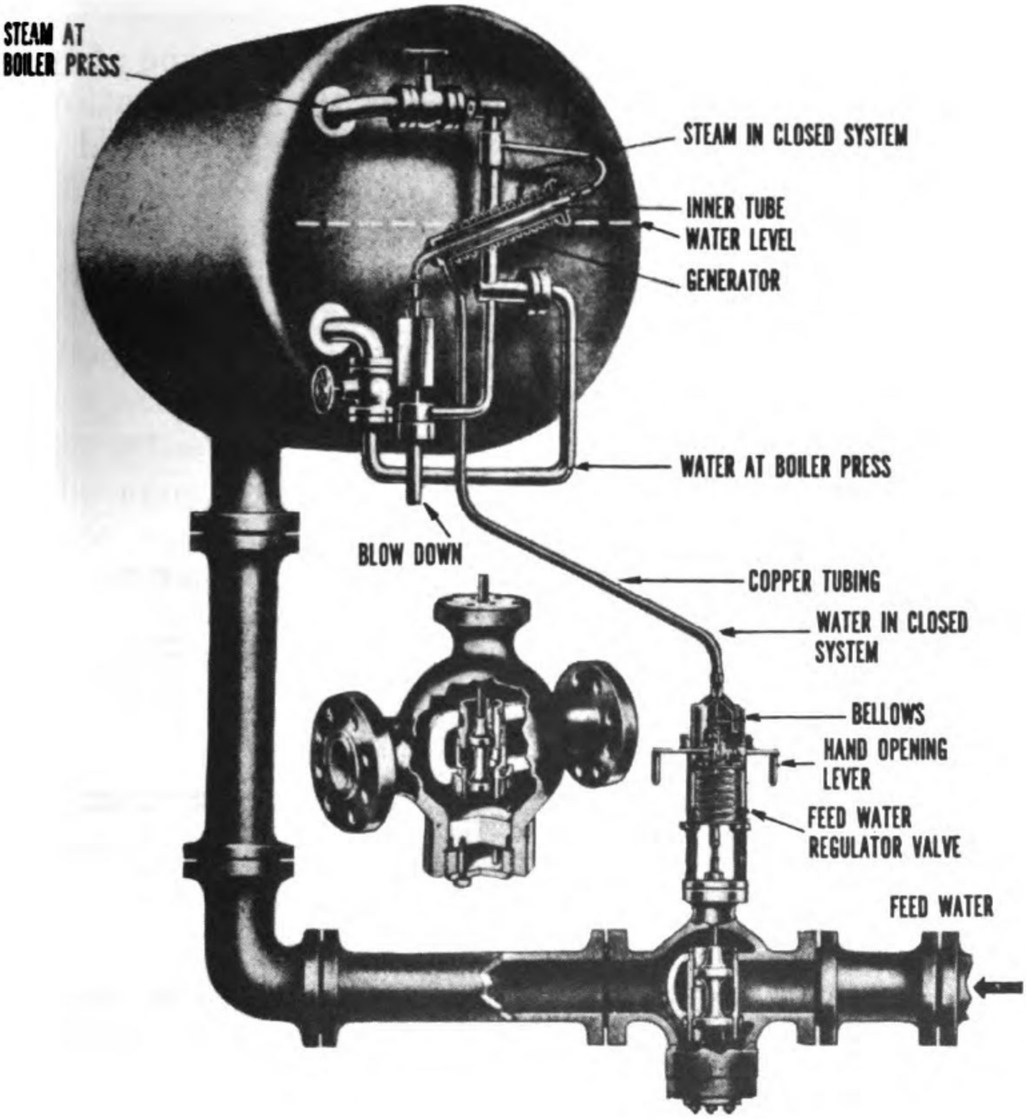


Figure 12–11.—Thermohydraulic feed-water regulator.

ates on a pressure differential caused by the level of the water.

When the steam demand decreases, the water level tends to rise. Cold water from the storage leg plus radiation secured from the generator fins causes steam in the closed system to condense, thereby reducing the pressure until the water levels in the inner and outer tubes are again approximately equal. The decrease of volume in the closed system causes the metal bellows to contract and, at the same time, partially closes the regulating valve.

Now take a look at the THERMO-EXPANSION type of feed-water regulator illustrated in figure 12–12. Operation of this type of regulator depends on the expansion and contraction of an inclined metal tube. The expansion tube is mounted on a steel frame. It is connected to the steam and water spaces so that the tube contains only steam when the water is at its lowest level.

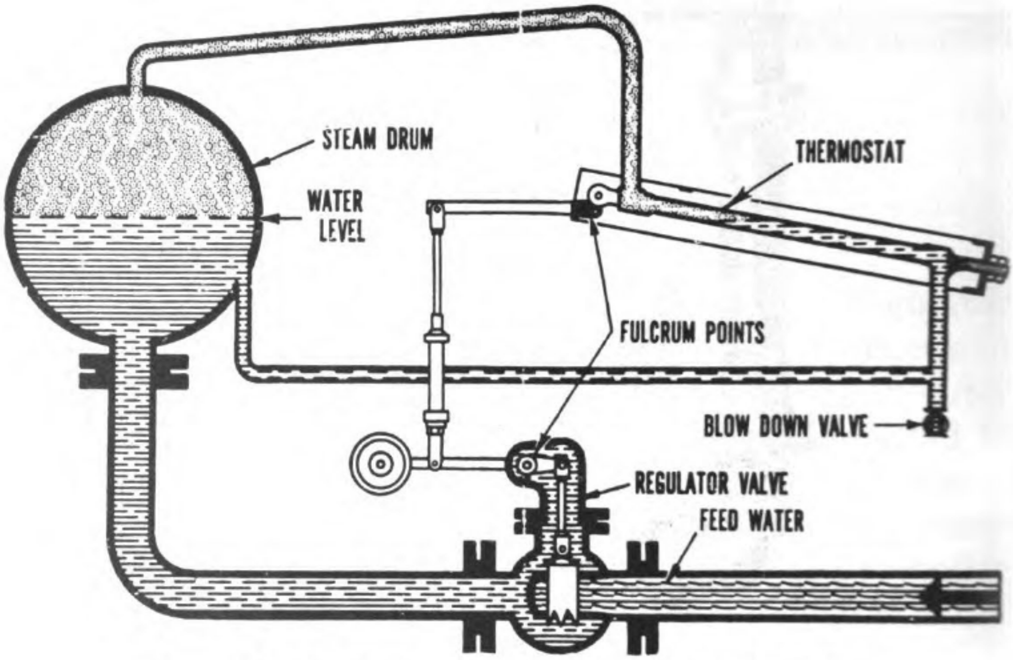


Figure 12–12.—Thermo-expansion feed-water regulator.

The tube is then expanded to its maximum length. As the water level in the boiler rises, the water rises in the tube, and the tube contracts in relation to the rise in water level. The tube is connected to a balanced valve in the feed line by a system of levers which move the valve as the water level changes.

The length of the tube and the width of the feed-valve openings are maximum when the water level is low and the tube is filled with steam. As the water level rises, the tube shortens, closing the feed valve and decreasing the rate of flow. Note that both of these regulators increase the flow of water as the level drops.

Fusible Plugs

FUSIBLE PLUGS are used on boilers to provide added protection against low water. They are constructed of bronze or brass with a tapered hole drilled lengthwise through the plug. They have an even taper from end to end of not less than 5/8 inch to the foot. This tapered hole is filled with a low-melting alloy consisting mostly of tin. There are two types of fusible plugs: fire-actuated and steam-actuated.

The FIRE-ACTUATED type is filled with an alloy of tin, copper, and lead, with a melting point of 445° to 450° F. It is screwed into the shell, or a special tube, at the lowest permissible water level. One side of the plug is in contact with the fire or hot gases, and the other side is in contact with the water. As long as the plug is covered with water, the tin does not melt. If the water level drops below the plug, the tin melts and is blown out. The boiler then must be taken out of service to replace the plug.

The STEAM-ACTUATED type of fusible plug is installed on the end of a pipe outside the drum. The other end of the pipe, which is open, is at the lowest permissible water level. A valve is usually installed between the plug and the drum. The metal in the plug melts at a temperature below that of the steam in the boiler. The pipe is small enough to prevent water from circulating in it. The water around the plug is much cooler than the water in the boiler as long as the end of the pipe is below the water level. However, if the water level drops below the open end of the pipe, the cool water runs out of the pipe and steam heats the plug. The hot steam melts the tin and it is blown out by the steam, warning the operator. This type of plug can be replaced by closing the valve in the plug line. It is not necessary to take the boiler out of service to replace the plug.

Fusible plugs should be renewed regularly once a year. DO NOT refill old casings with new tin alloy and use again. ALWAYS USE A NEW PLUG.

Valves

Boiler fittings include various types of valves, and each type is designed to serve a special purpose. With that thought in mind, let us consider some of the common types of valves, their location, and function.

The MAIN STEAM STOP VALVE, located at the superheater outlet, is, in most cases, a toggle-operated globe valve. The bearing surfaces on the valve disk and seat are usually made of a very hard erosion-resisting alloy, called STELLITE. Drain connections are fitted to the underside of the valve body, on either side of the valve disk. These drains can be used as bypass valves to equalize the pressure on both sides of the disk to facilitate opening of the main steam stop valve and to ensure proper drainage of that section of the main steam line. The main steam stop valve is either fully open or fully closed. The purpose of this valve is to put the boiler on the line, or to secure it.

The AUXILIARY STEAM STOP VALVE, generally the same as but smaller than the main steam stop, is installed so that the boiler may be connected to the auxiliary steam line. In saturated steam boilers and boilers with superheat control, the auxiliary steam stop is connected to an outlet of the steam drum. On integral superheater boilers, the valve is located at the desuperheater outlet connection.

Generally, two combined FEED STOP AND CHECK VALVES are installed on Navy boilers for controlling the amount of water admitted to the boilers and for shutting off the feed lines as desired. The feed check valve is designed to control the water level by varying the amount of water fed. The position of the check valve stem limits the amount of valve opening or disk travel. Check valves are located between the feed stop valve and the feed pump—in case the check valve becomes inoperative, that part of the feed line can be isolated. This arrangement will allow you to repair the check valve with pressure on the boiler.

The SURFACE BLOW VALVE (when installed) is located on the steam drum where it connects to the surface blow line which terminates at a scum pan inside the drum. This pan is located just below the normal water line. Its purpose is to remove scum from the surface of the water. As with most high-pressure valves of the globe type, the pressure is directed under the seat to facilitate opening.

BOTTOM BLOW VALVES, installed at the bottom of each water drum and header, are used to blow down the boiler, removing scale and other foreign matter that has settled in the lowest part of the water spaces. Boilers are also blown down to control concentration of solids dissolved in boiler water. Blow-down valves are located at the lowest point of the water sides.

The SAFETY VALVE is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler increasing beyond the safe-operating limit. It is installed, in a vertical position, directly to the steam safety-valve nozzle. Each boiler has one or more safety valves, and there are several different types in use.

Unlike the ordinary globe stop valves, safety valves are designed with a lip or extension on the underside of the valve disk. This increases the area against which the steam acts and gives it greater lifting power.

One type of safety valve used on steam drums is known as the HUDDLING CHAMBER type. Initial opening of this valve is caused by static pressure acting on the area of the disk. As the valve opens, the huddling chamber fills with steam, which builds up pressure on the lip or extension of the disk. This pressure increases the upward load against the spring, causing the disk to lift higher, or pop. A drop in pressure (blowdown) causes the valve to close. Blowdown adjustment is accomplished by means of an adjusting ring attached to the seat bushing. Raising this ring increases the blowdown; lowering it decreases the blowdown.

Another type of steam drum safety valve is referred to as the JET FLOW type. With this valve, both the reaction and the velocity of the escaping steam are put to use. Static pressure on the disk overcomes the spring tension, and causes initial flow of steam. When the escaping steam strikes against the guide, it is deflected downward against the nozzle ring and discharges into the body. This reactive force lifts the disk higher, increasing both the area of flow and the velocity. At pop lift, the position of the disk increases the area of the discharge so that it is greater than the area of the nozzle. Blowdown adjustment is controlled by externally regulating the metering screws which adjust the metering disks adjacent to orifices in the main valve disk guide. Screwing in the metering screws (turning them to the right) increases the blowdown; screwing them out decreases the blowdown.

The AIR COCK is a small, high-pressure globe valve located at the highest point of the steam space. Two important purposes of this valve are: (1) to allow air to escape while raising steam on a cold boiler or when filling a boiler with water; and (2) to allow air to enter when draining a boiler. When lighting off a cold boiler the air cock is one of the first valves to open. It is closed when sufficient steam has been generated to displace all the air in the steam space.

The ROOT VALVE is an emergency shut-off valve located between the source of power and the prime mover. An example is the valve located between the main steam stop valve and the main steam line.

OIL BURNER

The oil burner serves a vital function in the operation of a steam boiler, since its purpose, primarily, is to PREPARE THE FUEL FOR COMBUSTION. Two types of oil burner which may concern you in your work are direct-drive and belt-drive burners.

The DIRECT-DRIVE type of burner is built up from a rotating mainshaft, which is actually an extension of the motor shaft. The mainshaft extends through the burner length. It carries the motor rotor, fan, oil atomizer, and the pump drive worm. The shaft bears on two ball-bearing races, located in the gear case housing. The shaft speed is nominally 3,450 rpm.

The BELT-DRIVE type of burner depends on pulleys and V-belts to drive the burner shaft. The motor is mounted on the gear case housing. Using a standard 1,725 rpm motor, the pulley ratio is 2:1, resulting in a nominal speed of 3,450 rpm. On 25- and 50-cycle motors, the pulley ratios are proportioned to obtain a burner shaft rpm of 3,450. The belt-drive burner carries the same rotating elements as the direct-drive burner with the exception of the rotor.

Atomizer

The oil ATOMIZER is the heart of the entire burner system. Hence, it is appropriate that we point out a few main details concerning the design and function of this important device.

The UT is likely to find two types of mechanical atomizers used on Navy boilers—pressure and rotary. In the ROTARY type atomizer, oil is fed through a stationary tube to the inner surface of an atomizing cup, as shown in figure 12–13. The oil spreads over the surface of the rotating cup, and on reaching the edge of the cup is thrown off. The rotating cup imparts a whirling motion to the oil as it travels to the edge, and the resulting centrifugal force breaks up the oil into fine particles as it leaves the cup. A current of air from the fan (see fig. 12–13) flows around the atomizing cup and is given a whirling motion in the direction opposite to that of the oil. The streams of air and oil collide and are thoroughly mixed.

The amount of air supplied by the fan can be regulated by a damper on the suction side. This damper is usually controlled, together with the oil supply, by automatic or manual controls. The shape of the flame is determined by the nozzle through which the air is discharged.

PRESSURE-type atomizers are commonly used on burners of small heating units. The burners use multiple burner tips, and oil is delivered to the atomizing tip under high

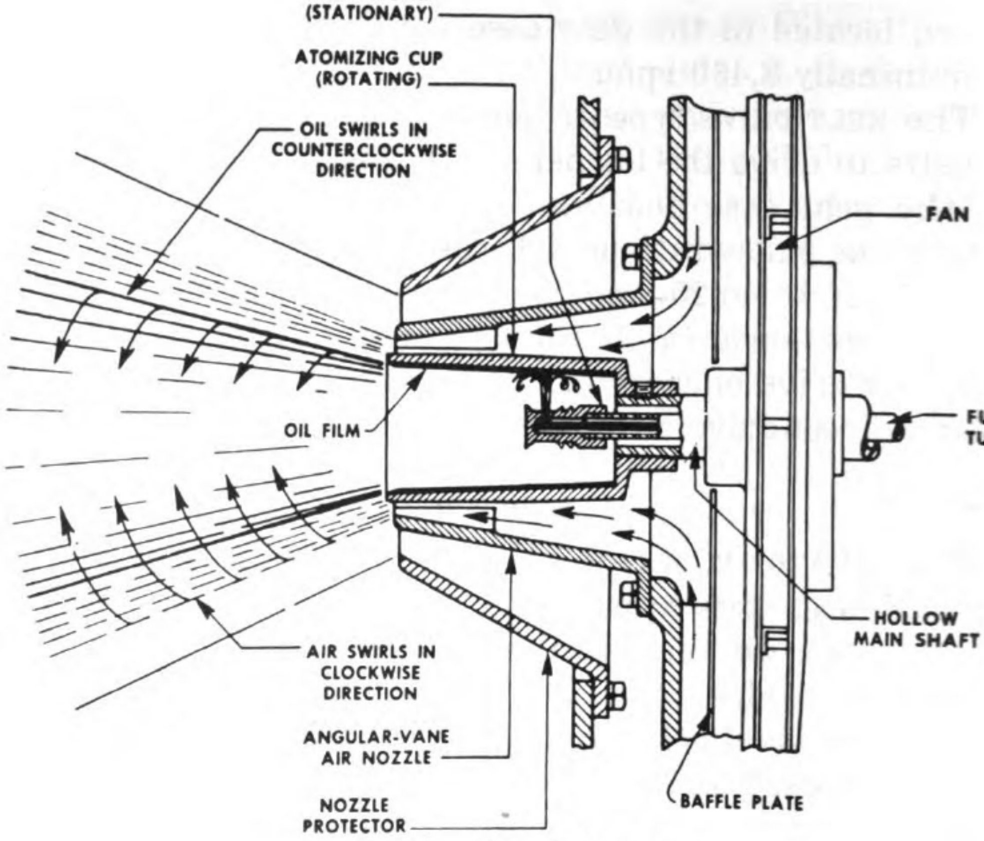


Figure 12–13.—Oil and air mixing.

pressure. Discharge of this high-pressure oil through the small tip results in a fine spray of oil. This spray is picked up by air from a built-in fan. The mixture entering the furnace consists of vaporized and atomized oil with sufficient air for complete combustion. The burner operates with on-and-off control and an electric spark system.

The STANDARD atomizer has a taper, the angle being somewhat different in the various burner sizes. On all burners, the atomizer is screwed onto the mainshaft. This thread is carefully cut on both shaft and atomizer. The atomizer screws into position on the shaft so that when coming into position, the shoulder of the atomizer presses squarely against a shoulder machined in the shaft. This arrangement ensures that the atomizer will line up perfectly with the shaft every time it is screwed into place.

For most burner applications, the standard atomizer is satisfactory. Occasionally, though, you may run into cases which require special atomizer shapes. For long, narrow fireboxes it may be necessary to use an atomizer without a taper so that the fire will be what is described as STRAIGHT SHOT, thereby avoiding impingement of fire on the furnace walls.

Steam Injector

The INJECTOR is a boiler FEED PUMP which utilizes the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into the same boiler. (See fig. 12–14.) This injection of water is many times the weight of the original jet of steam.

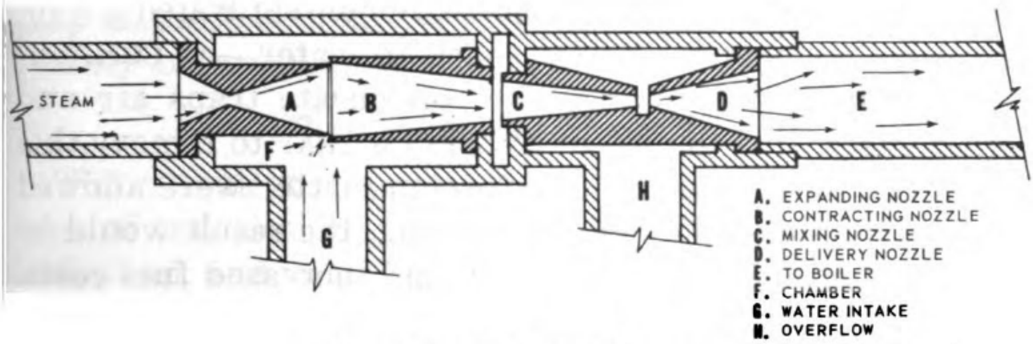


Figure 12–14.—Steam injector.

Injectors are available in various forms, but the principle of operation is basically the same in all forms. Steam is admitted to an EXPANDING NOZZLE or STEAM JET, and its pressure is reduced and its velocity greatly increased. The steam passes to a CONTRACTING NOZZLE, called the LIFTING TUBE or SUCTION JET. In passing from the expanding nozzle to the contracting nozzle, the steam carries the air in the chamber along with it and creates a vacuum.

The water to be pumped rises in the SUCTION PIPE and fills the SUCTION CHAMBER. It then enters the suction jet with the steam and passes to the COMBINING TUBE or DELIVERY NOZZLE. At this point, the water has attained a high velocity. Since the delivery nozzle is larger in area than the suction jet, the velocity is reduced and the pressure is increased enough to lift the check valve in the feed line, and the water enters the boiler. The steam has thus imparted kinetic energy to the water. This energy is converted from velocity to pressure in the delivery nozzle.

Correct action of the injector depends not only on the impact of the jet of steam, but also on the complete condensation of the steam in the delivery nozzle. Anything that tends to diminish rapid condensation—such as warm water—reduces the mechanical efficiency.

The thermal efficiency of the injector as a pump is about 2 percent, but as a combined pump and feed-water heater the heat efficiency is nearly 100 percent.

Steam Traps

In all steam-heated equipment, when saturated steam gives up its heat it changes back to water—or CONDENSATE. During this change the condensate traps air and other gases. It is the job of the STEAM TRAP to remove this from the steam lines. If this foreign matter were allowed to accumulate in the boiler or piping, the result would be a reduction in heating efficiency and increased fuel costs.

It is important that insulating films forming on heat transfer surfaces by condensate, air, and other gases be removed promptly. A layer of condensate insulates the same amount as an equivalent layer of asbestos-cement board. When allowed to accumulate, condensate is also likely to produce water hammer, causing serious damage from blown gaskets, burst tubes, pipes, and jackets, necessitating costly shutdowns and repairs.

A layer of gas insulation is comparable to a layer of ground cork. Moreover, gas in steam materially lowers the temperature of the mixture, thus reducing the temperature difference that produces heat transfer.

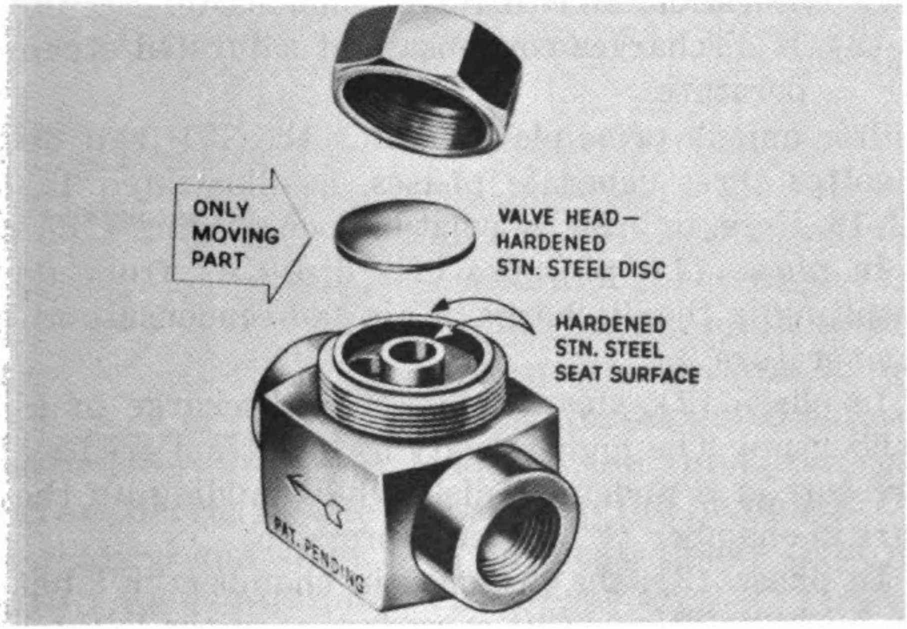
If it becomes necessary to replace a trap, careful consideration should be given the need for selecting the right one for the purpose at hand. This is not always a simple task in view of the many trap designs in use today.

Various qualities which are desirable in any trap include efficient operation, proper condensate capacity, and minimum installation and maintenance costs. In addition, consideration must be given to conditions of the particular system on which the trap will be used. If superheated steam is used, for example, you would want a trap designed for high temperature operation. As a further example, if the trap will be in an exposed position and subject to freezing you would need a type designed to withstand freezing of the condensate and possible rupture of the trap body.

In this discussion on steam traps, let us take a look at a few types with which you should be familiar. First take the IMPULSE type trap. Its design includes a lift which operates on the order of a vertical piston. The impulse trap is used, ordinarily, only where its operation can be readily observed.

Thermodynamic Steam Trap

The THERMODYNAMIC (or TD) steam trap is a new type of trap design, which consists of three simple parts: body, cap, and valve head. (See fig. 12–15.)


ONLY MOVING PART
VALVE HEAD—HARDENED STN. STEEL DISC
HARDENED STN. STEEL SEAT SURFACE
PAT. PENDING

Courtesy of Sacro Company, Inc.

Figure 12–15.—Thermodynamic steam trap.

The valve head, a hardened steel disk, is practically wearproof. It is the ONLY MOVING PART of this trap.

You will probably find the thermodynamic and bimetallic-element steam traps to be the most commonly used types at Seabee activities. From the maintenance standpoint, the thermodynamic trap is especially desirable because it has no critical clearances to choke up, no valve closing mechanisms to wear out, and no gaskets to spring leaks. In pipelines, a specially designed, screw-type strainer is used ahead of each TD trap to protect the valve head and seat from scale and other foreign matter, practically eliminating the need for maintenance.

Another major advantage in using the TD trap is that the same trap, without changes or adjustments, can be used for pressures ranging from 10 to 600 psi, and for all loads within the capacity range. It is available in four sizes: 3/8", 1/2", 3/4", and 1".

A few other features of the TD trap are:

(1) It is designed to permit self-draining, in which case there is no danger of freezing when installed in a vertical line with an open discharge pipe.

(2) It is not affected by superheat, water-hammer, vibration, and corrosive condensate.

(3) It discharges condensate at saturated steam temperature.

The unique principle on which the TD trap operates involves three separate phases, as illustrated in figure 12–16. Here, in brief, is what happens during each phase.

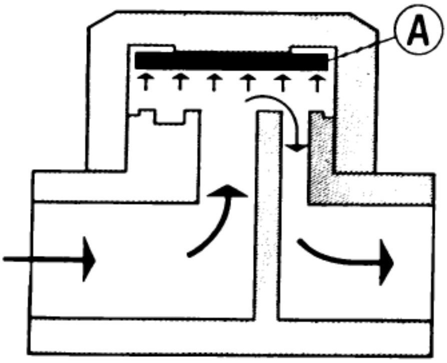
In phase (1), pressure lifts disk "A" from its seat, resulting in the discharge of air and condensate at steam temperature.

In phase (2), steam follows the discharge of air and condensate. The high velocity of the steam creates a low pressure area under the disk, while building up the pressure in chamber "F" by recompression.

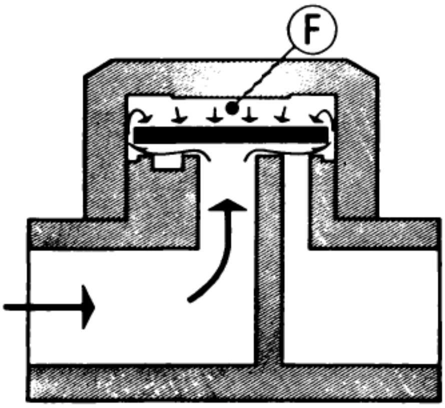
In phase (3), the pressure in chamber "F" has built up to the point where it exceeds that of the low pressure area and the incoming steam combined. This pressure is

HOW IT WORKS!

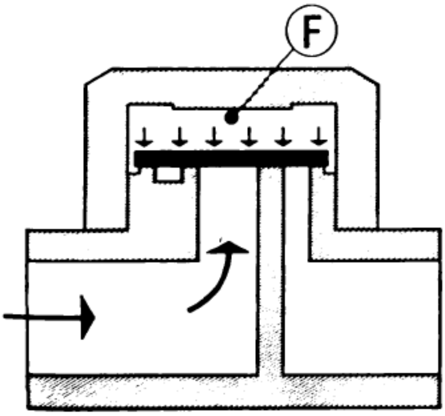
Only the Sarco "TD" THERMODYNAMIC steam trap uses this unique operating principle which permits the trouble-free simple design.



❶ Pressure raises disc "A" from seat...immediate discharge of air and condensate at steam temperature. (reverse the disc and trap will discharge 30° below steam temperature!)



❷ Steam follows...high velocity creates low pressure area under disc...builds up pressure in chamber "F" by recompression....



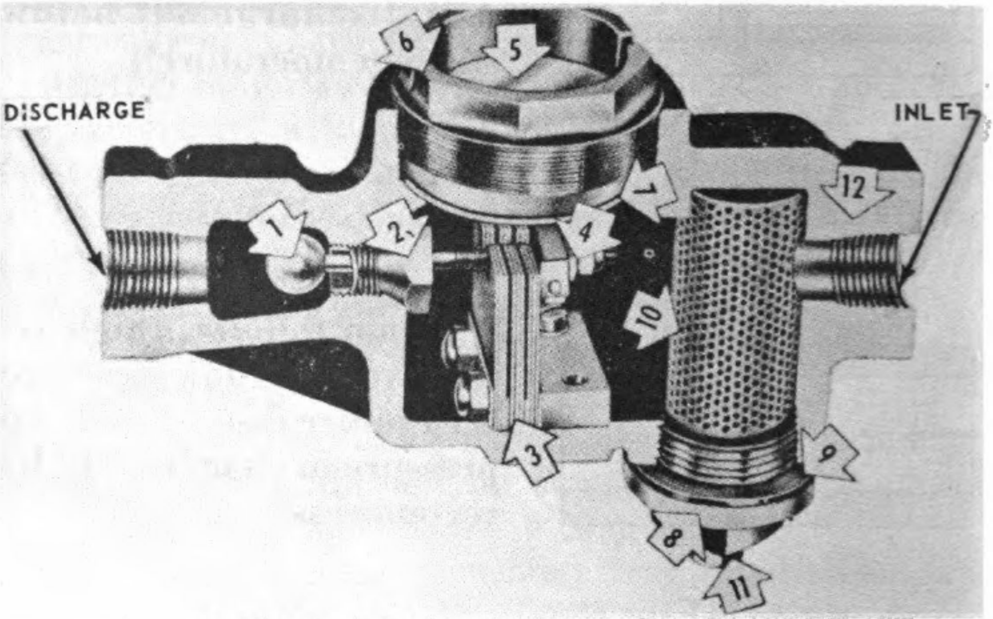
❸ The pressure in chamber "F", acting on the full top area of the disc, exceeds the combined force of the incoming steam and the low pressure area...and immediately forces the disc down closing the inlet. As condensation decreases the pressure in the chamber, the disc is raised and steps 1 or 2 repeat. Closes tight on no load...no continuous leak.

Courtesy of Sacro Company, Inc.

Figure 12-16.—Operating principle of TD steam trap.

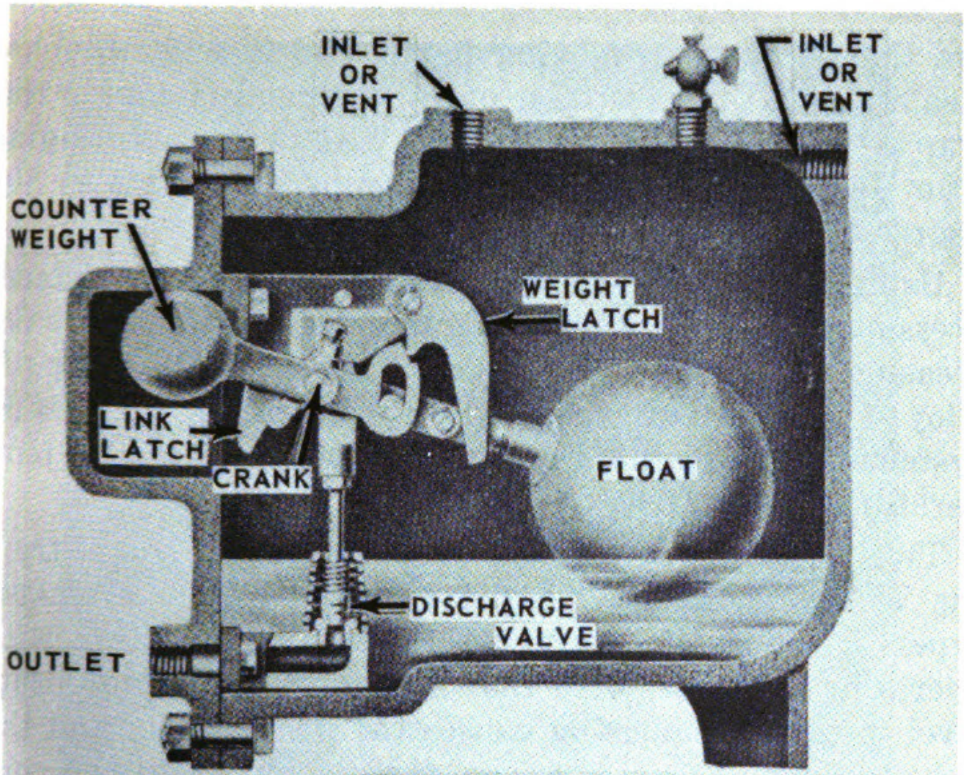
exerted on the top surface of the disk, forcing it down and closing the inlet. As condensation then lowers the pressure in the chamber, the disk rises to repeat phase (1) or (2) of the operation.

The BIMETALLIC-ELEMENT actuated steam trap, illustrated in figure 12–17, is a desirable trap for systems with fluctuating pressures or changing characteristics. The initial cost of this trap not only is moderate, but its upkeep also is especially low. Other advantages worth noting

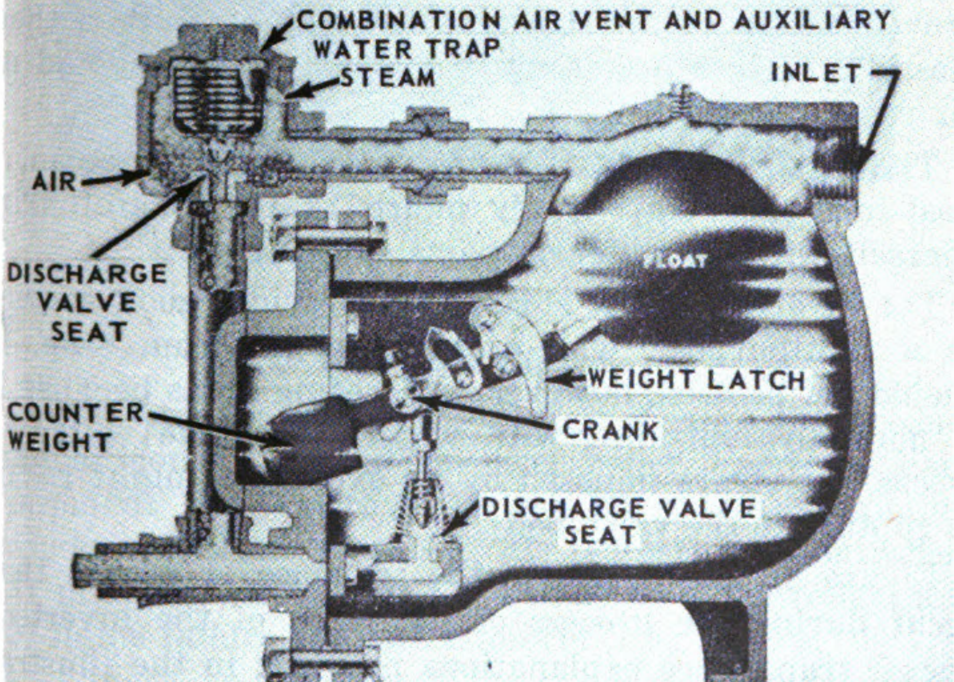


1. Ball valve, chrome steel, mirror finish.
2. Valve seat, corrosion-resistant steel.
3. Bimetallic thermal unit.
4. Discharge temperature setter.
5. Optional observation glass, heat resistant.
6. Cover plate.
7. Gaskets, asbestos - metal.
8. Removable strainer plug.
9. Gasket, asbestos - copper ring type.
10. Strainer basket, phosphor bronze mesh or corrosion - resistant steel.
11. Drain plug for cleaning while in operation.
12. Body, semi-steel, cast steel, or alloy steel.

Figure 12–17.—Bimetallic-element steam trap.



STRAIGHT–FLOAT TYPE



FLOAT–AND–THERMOSTATIC TYPE

Figure 12–18.—Float-operated steam traps.

are that it has few moving parts, and it will not blow steam. With the exception of the thermal element, this trap is suitable for use on systems with pressures ranging from 10 to 600 psi, or working temperatures up to 800 degrees.

Using a bimetallic-element trap on high or low steam pressure systems is simply a matter of increasing or decreasing the number of metallic leaves in the trap. If alloy steel bodies are specified you can use these traps on systems with pressures up to 2,000 psi, or working temperatures up to 1,000° F.

Two variations of the float-operated type of steam trap, the STRAIGHT-FLOW and the FLOAT-AND-THERMOSTATIC types, are illustrated in figure 12–18. In connection with operating features, note that an increase in condensate level in the trap housing causes the float to rise and the valve to open. Steam pressure forces liquid into the condensate-return pipe, causing the water level to drop and the float to sink so as to close the discharge valve. Improved models of the straight-float traps feature a thermostatic bellows accessory that closes or opens, and an air vent.

The INVERTED-BUCKET steam trap is another form of float-controlled trap. Study figure 12–19 to familiarize yourself with the different parts of this trap.

The inverted-bucket steam trap provides good service as a multipurpose, wide-pressure-range steam trap. It should not be used, however, in freezing areas because it is normally half-filled with water. Were the water to freeze, the strain imposed by its expansion might result in rupture to the valve body.

Figure 12–20 illustrates the sequence of events that occur during the process of operation of the inverted-bucket trap. Since explanations provided in the illustration will help you understand what takes place during different phases of the operation, details need not be spelled out here.

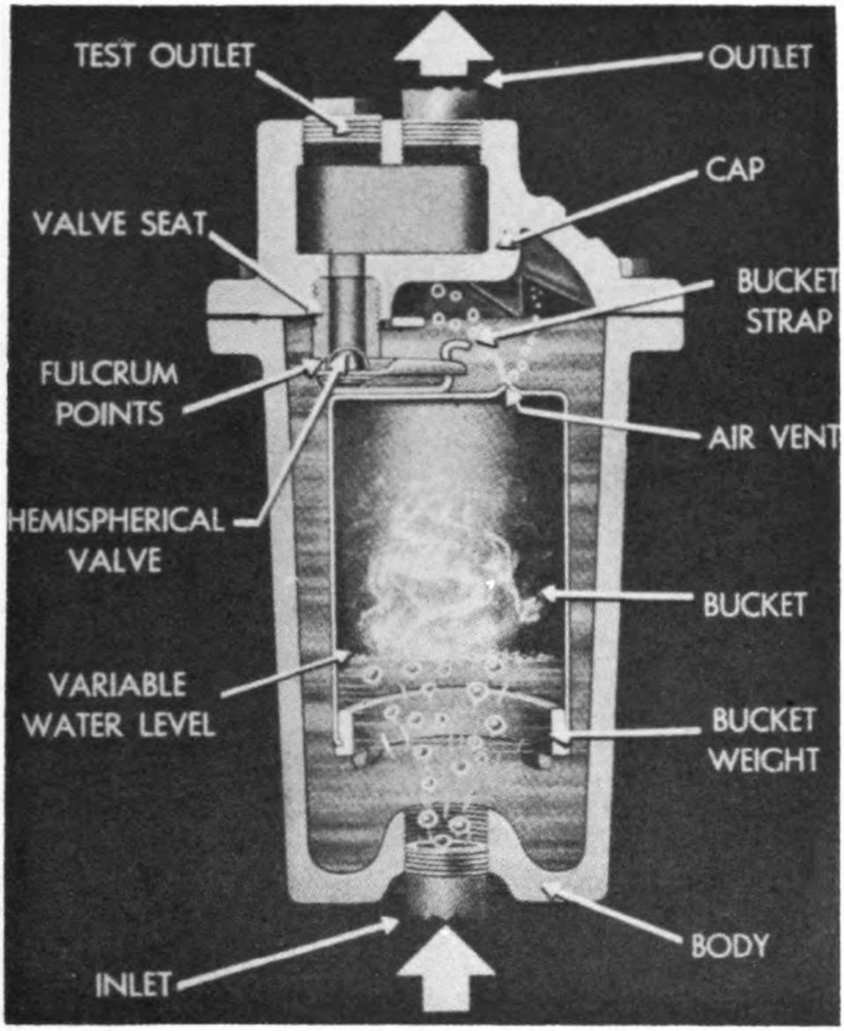


Figure 12–19.—Inverted-bucket steam trap.

Automatic Controls

Automatic controls are a big asset since they reduce manual control of the furnace, boilers, and auxiliary equipment. Those with which the UT should be familiar include: (1) float controller; (2) temperature controller; (3) pressure controller; (4) combustion controller; and (5) flame failure and operation controls.

Float Control

Floats in boiler instruments work on the same basic principle as the float in the flush-tank type of water

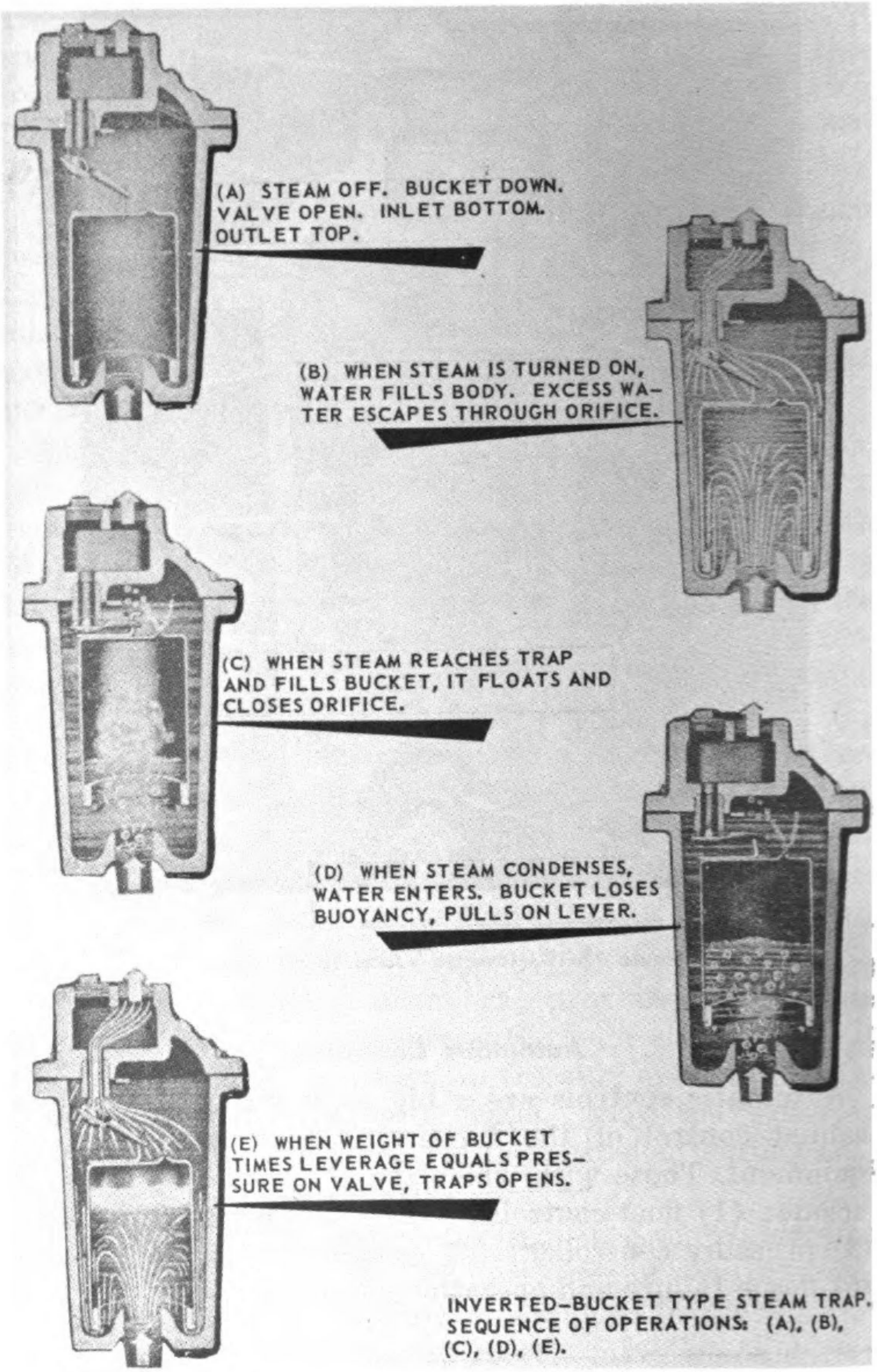

(A) STEAM OFF. BUCKET DOWN. VALVE OPEN. INLET BOTTOM. OUTLET TOP.
(B) WHEN STEAM IS TURNED ON, WATER FILLS BODY. EXCESS WATER ESCAPES THROUGH ORIFICE.
(C) WHEN STEAM REACHES TRAP AND FILLS BUCKET, IT FLOATS AND CLOSES ORIFICE.
(D) WHEN STEAM CONDENSES, WATER ENTERS. BUCKET LOSES BUOYANCY, PULLS ON LEVER.
(E) WHEN WEIGHT OF BUCKET TIMES LEVERAGE EQUALS PRESSURE ON VALVE, TRAPS OPENS.
INVERTED-BUCKET TYPE STEAM TRAP. SEQUENCE OF OPERATIONS: (A), (B), (C), (D), (E).

Figure 12-20.—Sequence of operations in inverted-bucket trap.

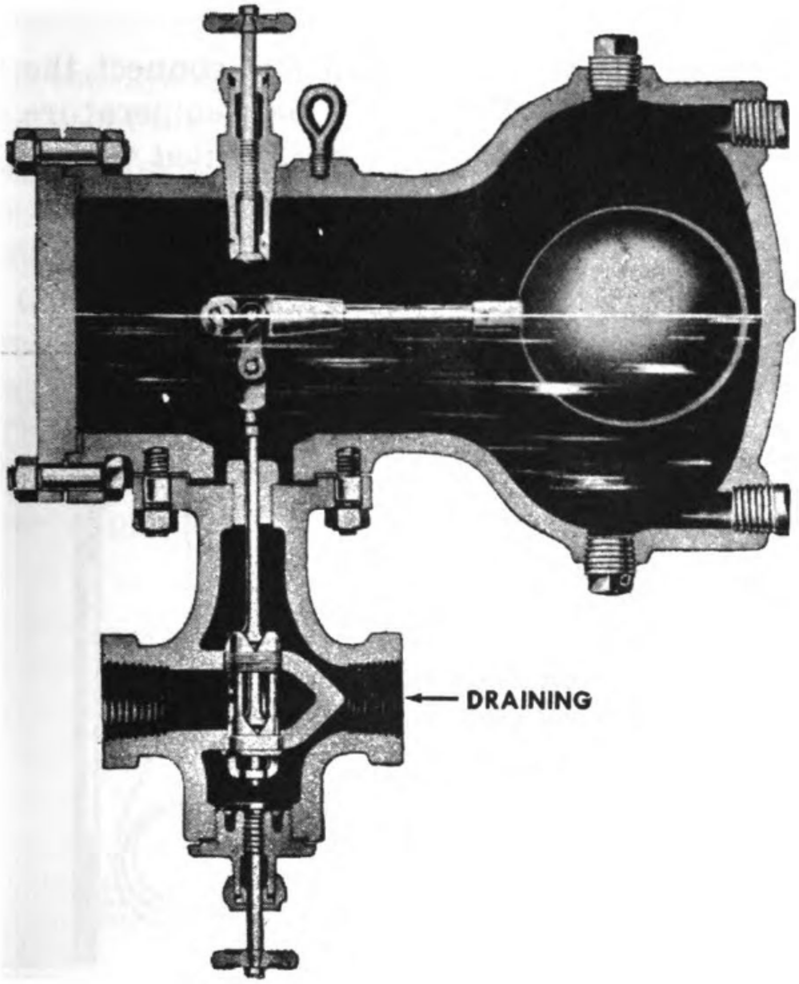


Figure 12–21.—Float controller.

closets. Float, or level control, depends on the level of fluid in a tank or boiler to indicate the balance between the flow out of and the flow into the equipment, and to operate a controller to restore the balance.

A float is often used to measure the change in level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the level drops. Figure 12–21 illustrates one of the methods used to accomplish this. Here the float is connected to the control valve.

Temperature

A typical temperature controller consists of a regulating valve, a temperature bulb, a metal bellows to operate the valve, and the necessary tubing to connect the valve to the bellows (see fig. 12–22). The temperature bulb, tube, and bellows are filled or partially filled with a liquid suitable for the temperature the valve is to control.

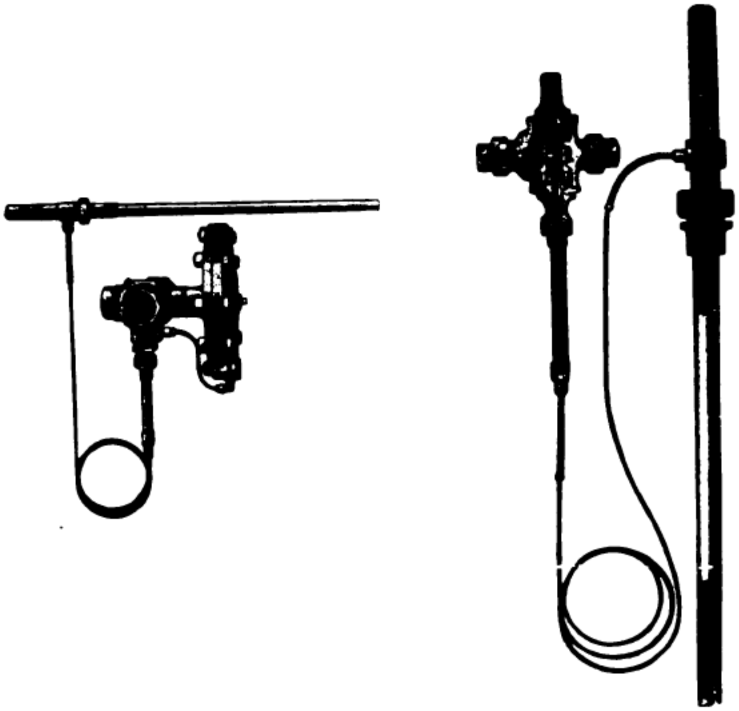


Figure 12–22.—Temperature regulators.

The bulb is inserted wherever temperature is to be controlled as in the feed-water heater or hot-water heater. The valve is mounted in the steam or hot-water line supplying the heat. The liquid in the bulb expands and vaporizes when heated, and builds up a pressure in the metal bellows, which is resisted by the spring. Any change in pressure in the system, due to a change in temperature of the bulb, causes a corresponding movement of the valve to restore the temperature to the desired point.

Pressure

Pressure control is the process of maintaining a difference of pressure between two points in the system. One type of control maintains a definite pressure in one part of the system, while the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-reducing valve which maintains a definite pressure on the discharge side of the valve by controlling the flow of steam, air, or gas through the valve. (See fig. 12–23.)

A second type of control maintains a definite difference in pressure between two points, and also controls the flow. This type of control is often applied to boiler feeding to maintain a fixed difference between the pressure of water supplied at the feed valve and the pressure in

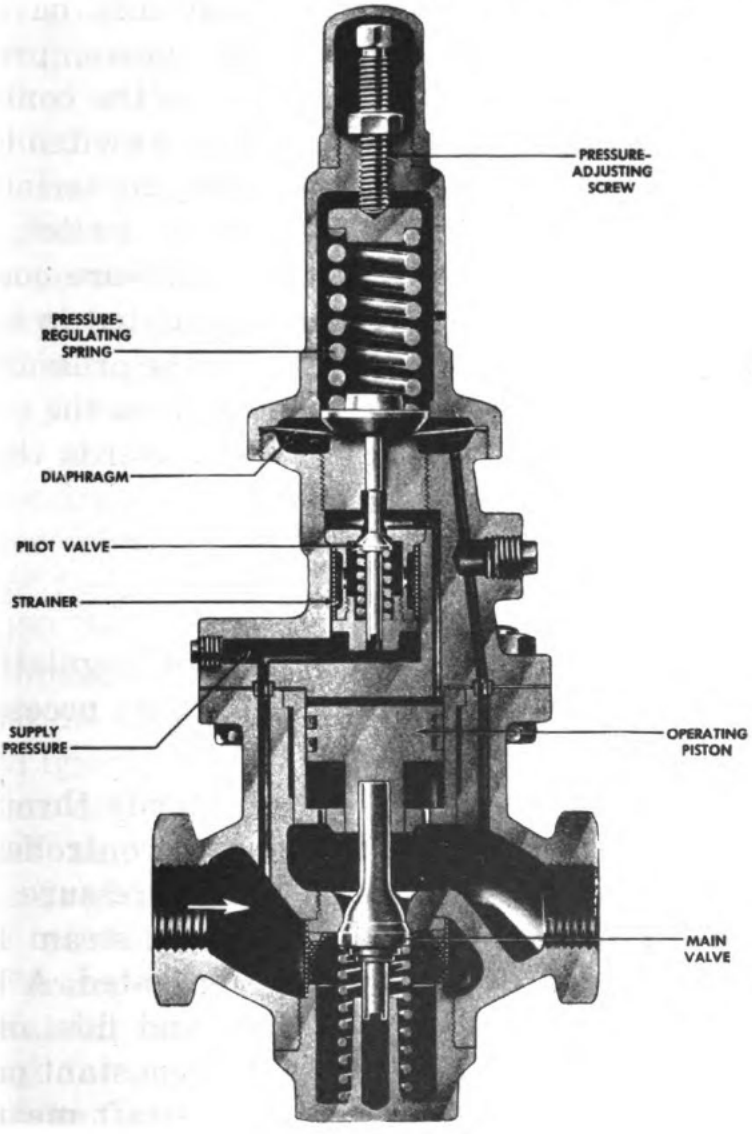


Figure 12–23.—Auxiliary pilot-valve-operated pressure regulator.

the boiler steam drum. The pressure controller may consist of a self-contained device which operates the regulating valve directly, or it may consist of a pressure-measuring device such as a Bourdon-tube gage which operates a pilot or relay valve. The valve positions the regulating valve or mechanism to maintain the desired conditions.

An electrical pressure controller can be used to maintain pressure between two given points. This type of control is often applied to boiler steam pressure to cut in the burner on a set low pressure, and to cut out the burner on a set high pressure. It may also be used to control air, liquid, or noncombustible gases, providing their chemical content is not injurious to the control. Its design includes a bellows, which actuates a switch to make or break an electrical circuit in response to variations in pressure. Some types contain a mercury switch, others employ a snap switch. The electrical pressure controller is located above the water line. It is mounted in a fitting provided by the manufacturer or beside the pressure gage. A siphon must always be connected between the pressure control and the boiler, with the loop towards the front or back of the control.

Combustion

Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam.

Combustion control is obtained ordinarily through the use of pressure or pressure-differential controllers. Demand for steam is indicated by the steam pressure. A drop in pressure indicates that there is more steam flowing away from the boiler than is being generated. A balance between flow of air into the furnace and flow of gases away from the furnace is indicated by a constant pressure or draft in the furnace. An increasing draft means that flow of gas away from the furnace is greater than flow of air into the furnace. The controller regulates the flow of steam, air, and fuel for proper operation.

Flame Failure and Operation Controls

Frequently, on full-automatic fire-tube boilers, you will find an electronic-type device provided for the control of flame failure. The device will provide automatic start and operation of the main burner equipment. The controls are so designed that they close all fuel valves, shut down the burner equipment within 4 seconds after a flame failure, and actuate an alarm. The controls also create a safety shutdown within 4 seconds after deenergization of ignition equipment if main burner flame is not properly established or fails during the normal starting sequence. The controls must create a safety shutdown if the pilot flame is not established and confirmed within 7 seconds after lighting. A safety shutdown requires manual reset before operation can be resumed and prevents recycling of the burner equipment.

In all initial starts and subsequent restarts during on-and-off cycling the automatic operation controls are designed to provide the following services:

—Low fire start

—Precombustion and postcombustion scavenging, except for fully automatic boilers having capacities of 2,000 lbs. per hour or less, which require no postcombustion scavenging (during pre- or post-combustion scavenging periods the blower should be on, and ignition, pilot, and main fuel valve should be off)

—Time delay of at least 5 seconds between ignition of pilot and opening of main fuel valve (except for gas-fired boilers and light oil-fired boilers with pilot, the pilot flame must be established and confirmed before opening of the main fuel valve)

—Trial-for-main-burner-ignition period (Note: The trial for ignition period is the time the pilot flame and/or ignition is on after the main fuel valve opens.)

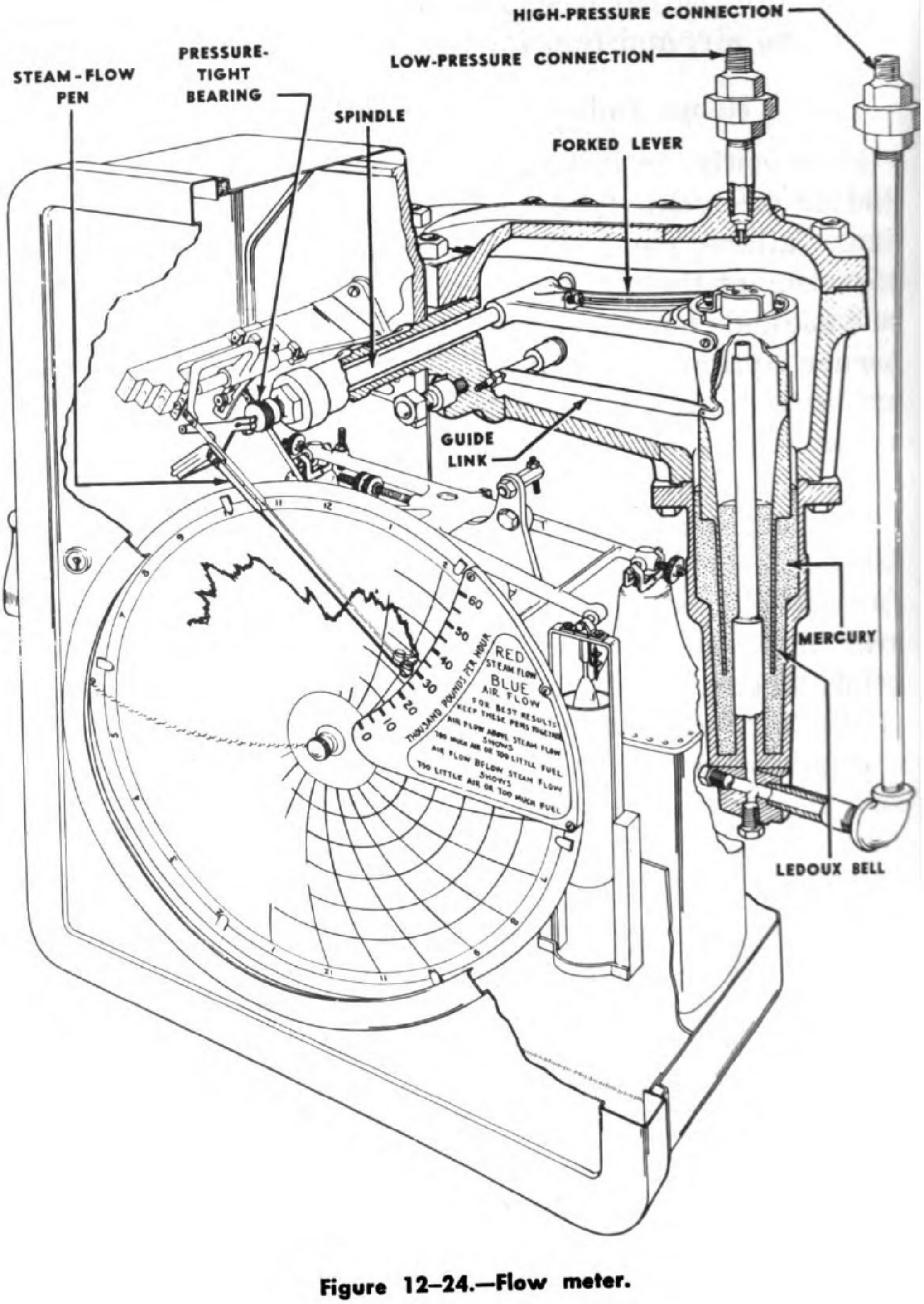


Figure 12–24.—Flow meter.

—Proper shift of operation from operating control to the combustion operating controls after main burner flame has been properly established and confirmed

In case of supply voltage failure, the operating control will recycle when power is restored. The electronic device should readily detect flame under all firing conditions of both pilot and main flame, but should not be actuated by hot refractory or any other hot body. The controls are designed so that failure of any vacuum tube or other component will cause a safety shutdown, or result in a safety interlock to prevent recycling of the control.

Instruments and Meters

A pressure gage is essential for safe operation of a boiler plant. However, use of additional instruments, such as draft gages and flow meters, increases safety and promotes efficiency. All of these instruments may be either indicating or recording.

STEAM FLOW METERS.—Meters used to measure quantities may be divided into two general types: those indicating rate, such as flow meters; and those indicating the total, such as scales. Many devices measure and indicate the pressure of steam flow. One is illustrated in figure 12–24. This meter uses a weighted inverted bell (called a Ledoux bell) sealed with mercury. The bell moves up and down as the rate of flow changes. The movement is transmitted to a pen which records the flow.

STEAM-FLOW AIR-FLOW METER.—A combination air- and steam-flow meter is shown in figure 12–25. This meter is used as a guide in controlling the relationship between air required and air actually supplied to burn the fuel. The rate of steam generation is used as a measure of air necessary to burn the required amount of fuel. The flow of gases through the boiler setting is used as a measure of air supplied.

Essential parts of the meter are two air-flow bells supported from knife edges on a beam, which is supported by other knife edges, and a mercury displacer assembly

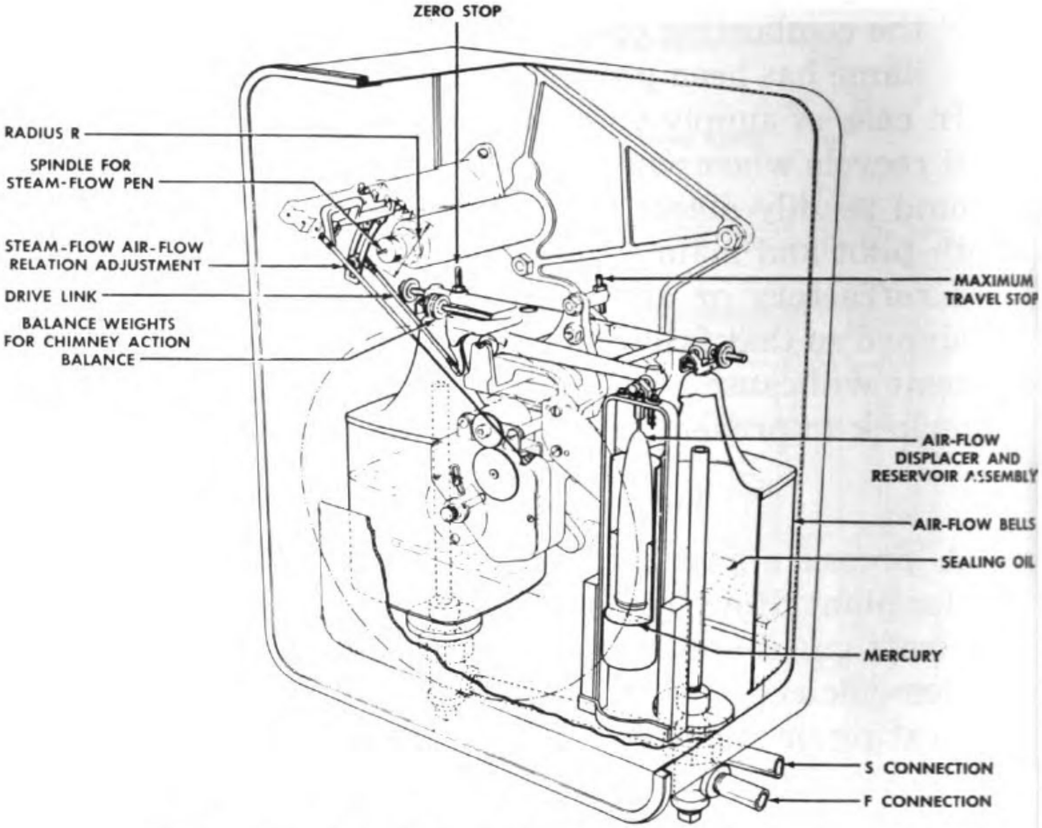

ZERO STOP
RADIUS R
SPINDLE FOR STEAM-FLOW PEN
STEAM-FLOW AIR-FLOW RELATION ADJUSTMENT
DRIVE LINK
BALANCE WEIGHTS FOR CHIMNEY ACTION BALANCE
MAXIMUM TRAVEL STOP
AIR-FLOW DISPLACER AND RESERVOIR ASSEMBLY
AIR-FLOW BELLS
SEALING OIL
MERCURY
S CONNECTION
F CONNECTION

Figure 12–25.—Air-flow mechanism of a boiler meter.

supported by a knife edge on the beam. The bottoms of the bells are sealed with oil and the spaces under the bells are connected to two points of the boiler setting.

DRAFT GAGES.—A draft gage is a form of pressure gage. In boiler practice, the term draft usually refers to the pressure difference producing the flow. Drafts are pressures below atmospheric pressure. They are measured in inches of water. A draft gage is essential to boiler operation. Its use increases the safety of operation.

Two or more draft gages are required for economical boiler operation. They inform the operator of the relative amount of air being supplied to burn the fuel and the condition of the gas passages. Draft gages are made as indicators, recorders, or both. The measuring element uses a column of liquid, a diaphragm, or a bellows. The liquids used are oil, water, or mercury.

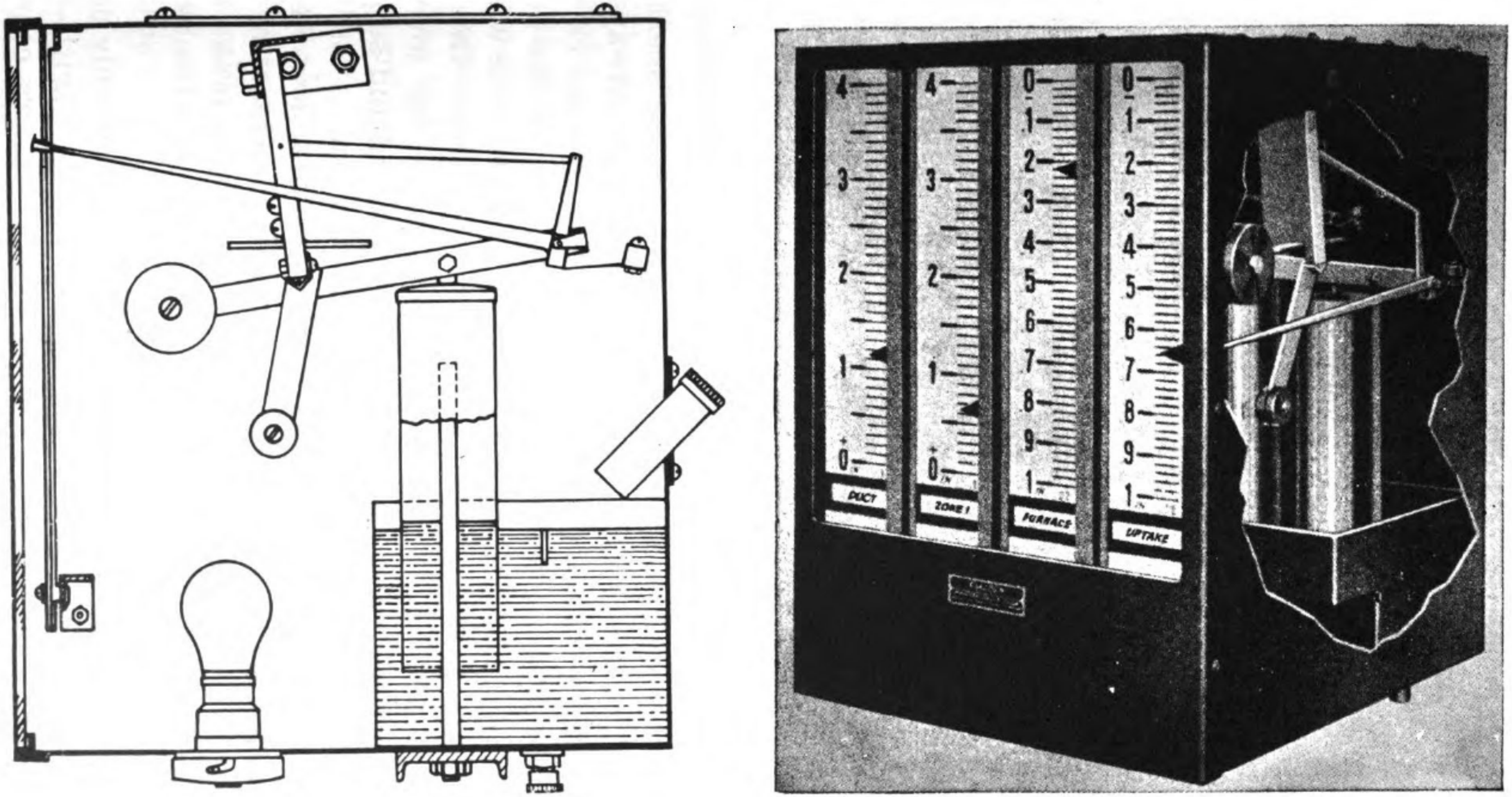


Figure 12-26.—Liquid-sealed draft gage.

The gage shown in figure 12–26 is an indicating type which operates on the same principle as the U-tube (difference between the levels of the liquid in the two legs is a measure of the draft).

The bottom of the inverted bell is sealed with oil or mercury, depending on the magnitude of the draft or pressure to be measured. It is supported by knife edges on the beam to reduce friction as much as possible. The weights counter-balance the weight of the bell, and the pointer is returned to zero. The source of draft is connected to the tube which projects into the inverted bell so that an increase in draft causes the pointer to move down.

CO_2 METER.—This is an instrument for determining, indicating, and recording the percentage of CO_2 (carbon dioxide) in the products of combustion. The principle of this instrument is based on the fact that the specific weight of flue gas varies in proportion to its CO_2 content (CO_2 being considerably heavier than the remaining parts of the flue gas).

Tanks

A boiler plant and heating system cannot be operated so the flow of water and the flow of steam are always in balance. The demand for water by the boiler may exceed the rate at which water is being returned from the heating system, or the water may be returning at a rate which is greater than the requirements of the boiler. One or more tanks can be installed to compensate for uneven flows and for differences between the demand and supply of water. These vessels are called surge tanks.

Sudden reductions in pressure may lead to violent steam formation. Flash tanks help eliminate disturbances in the piping system caused by this process. These tanks are usually small and located near the traps where the pressure release occurs.

The storage type of hot-water heater is commonly used to furnish laundries, hospitals, and kitchens with hot water for washing and cleaning. These heaters consist of a horizontal or vertical tank with a steam-heating element near the bottom.

FUEL FACTS

Fuel plays a vital part in keeping Navy boilers in efficient operating condition. In acquiring a basic knowledge of the utilities field, make sure you familiarize yourself with such terms as FLASH POINT and FIRE POINT of oil, as well as the correct procedure for testing for bottom sediment and water.

The FLASH POINT of an oil is the lowest temperature at which the oil will give off a vapor, which, when combined with air, is flammable.

The FIRE POINT of an oil refers to the temperature at which the oil gives off sufficient vapor to remain ignited after flashing. This temperature is higher than the flash point.

The VISCOSITY of an oil is the measure of its internal friction or resistance to flow. Viscosity is of particular importance in the case of heavy fuel oils, which must be heated in order to reduce their viscosity to a point where they can be pumped.

The term SPECIFIC GRAVITY indicates the ratio of the weight of a given volume of any substance to the weight of an equal volume of water at standard conditions of temperature and pressure. Specific gravity is determined by means of a hydrometer.

The PERCENTAGE OF IMPURITIES present in an oil can be determined by either of two methods: distillation or centrifuge. The latter method will be described presently. First, let us point out that water and sediment are the most common impurities in oil. Water in fuel oil is undesirable because its emulsification interferes with proper combustion. Sediment causes wear on pump valves and burners, and clogs the burner orifices.

The Centrifuge Method

The CENTRIFUGE METHOD is appropriately named since it requires the use of a device called the centrifuge. The centrifuge consists of a top piece in which two metal tubes, carrying glass tubes graduated at 100 milliliters, are held in carriers. The top piece with the tubes is rotated on a spindle at about 1,500 revolutions per minute either by hand or electric motor.

In testing for bottom sediment and water in an oil, using the centrifuge method, here is the procedure to follow: Start by measuring exactly 50 milliliters of 90 percent benzol into each of the two centrifuge tubes. Then add exactly 50 milliliters of the oil to be tested to each tube. The two tubes should then be stoppered tightly and shaken vigorously until the contents are thoroughly mixed. With that done, immerse the tubes to the 100 milliliter mark in a water bath maintained at 120° F.

After 10 minutes in the water bath, remove the two tubes and place them on opposite sides in the centrifuge and whirl for 10 minutes at a rate of 1,400 to 1,500 revolutions per minute. Now remove the tubes and make a reading of the combined volume of water and sediment at the bottom of each, estimating to 0.1 milliliter if necessary. After making a record of your reading, replace the tubes in the centrifuge and whirl them for another 10 minutes. Then remove the tubes and make another reading of the volume of water and sediment as before.

The whirling operation must be repeated until the combined volume of water and sediment in each tube remains constant for three consecutive readings. Ordinarily, you probably will have to make not more than four whirlings.

Remember that the combined total volume of water and sediment should be read on each tube, estimating to the 0.1 milliliter if necessary. The sum of the two readings is recorded as the percentage of water and sediment in the oil, centrifuge method.

With care and proper attention to details, duplicate determinations of water and sediment by this method should not differ by more than 0.2 milliliter—provided the centrifuge tubes are accurate and readable to this degree.

QUIZ

1. How does this text define the term boiler?
2. What is superheated steam?
3. What is a stationary boiler?
4. What is the type of boiler (fire-tube or water-tube) in which the products of combustion pass through the tubes and the water surrounds the tubes?
5. What fuel is commonly used to fire the Scotch boiler?
6. Explain the flow of gases in the Scotch boiler.
7. What is a handhole?
8. How are baffles usually arranged on bent-tube (water-tube) boilers?
9. What is the purpose of breechings?
10. Where is the root valve located?
11. When are two water-gage glasses required on a boiler?
12. What boiler fitting has a high- and low-water alarm whistle?
13. What function does the automatic feed-water regulator perform?
14. Name two types of fusible plugs.
15. Which is the most important of the many boiler fittings?
16. How is blowdown adjustment controlled with the huddling-chamber type of safety valve?
17. What is the chief function of the oil burner?
18. What two types of mechanical atomizers in fuel oil burners are you likely to find being used on Navy boilers?
19. What are the three parts of the thermodynamic steam trap?
20. Of what does a typical temperature controller consist?
21. What is meant by combustion control?
22. What instrument uses a Ledoux bell?
23. What is a CO_2 meter?
24. When you speak of the fire point of an oil to what are you referring?
25. What are the most common impurities in oil?

CHAPTER 13

OPERATION AND MAINTENANCE OF STEAM BOILERS

The operation and maintenance of steam boilers are important functions of the Utilities Man's job. The role of steam in providing a variety of useful services at Seabee activities indicates the responsibility involved on the part of personnel who operate and service boilers.

Because of the broad scope of duties involved in operating and servicing of boilers, you can readily understand why this one chapter will not tell you all you need to know about the subject. In this connection, let us note that the duties described in succeeding sections are typical of those you should be able to perform at 3 or 2 level. Learning well how to carry out the procedures given will help you to acquire the basic foundation on which to build more advanced skills. Another point to note is that various types or sizes of boilers are used in describing procedures for various operations. This is an advantage since you will probably be working with different makes and sizes of boilers.

Let us explain further that procedures for operating and servicing steam boilers will vary among different types, sizes, and models of boilers. For best results, therefore, always check and follow the procedure specified in the instruction manual supplied by the manufacturer of the unit with which you are working.

This chapter also discusses boiler water tests, outlining the procedure applicable to some of the tests which you as a UT 3 or 2 should be able to make. As you are well aware by now, your work with boilers is going to involve a lot of responsibility. By applying yourself to study and practice, however, you can acquire the skill and knowledge necessary to perform your duties with maximum efficiency.

BOILER OPERATION

The operation of a boiler consists of three major phases: (1) preparing and starting, (2) operating, and (3) securing. If you have little or no experience in operating boilers, a good place to start would be with a small, simple-type unit—then move up gradually to the larger and more complex units. The following guide outlines the principal steps to follow in operating a small, oil-fired, SINGLE BURNER UNIT. If you get an opportunity for practice, see if you can follow through the complete operating procedure. As each step is completed, indicate by placing a check mark in the box provided on the left of the guide.

Preparing and Starting

☐ 1. If the boiler is cold, open the air vent cock.

☐ 2. Line up feed line. Open feed stop, suction, and discharge valves from the feed supply to the boiler. Start the boiler feed pump.

☐ 3. Check water level in gage glass.
   - (a) If boiler is full, lower water level by opening the slow-opening bottom blow valve, then the quick-opening valve. When water level has been lowered to lighting off level, close the slow-opening bottom blow valve and then the quick-opening valve.
   - (b) If boiler water level is low, throw the switch of the feed water regulator to AUTOMATIC FEED and raise the level to normal.

☐ 4. Try water level in water gage glass by opening the gage glass blowdown valve.

☐ 5. Check valve to pressure gage. Must be open.

☐ 6. Check main steam stop valve. Must be closed.

☐ 7. Check all access doors on casing and fire box. Must be closed.

☐ 8. Clean fuel strainers.

☐ 9. Line up fuel supply.

  a. Open suction valve on fuel tank.
  b. Open root valve on manifold to burner.
  c. Make sure atomizer valve is closed.

☐ 10. Check working parts for proper lubrication. Wipe up oil in drip pan.

☐ 11. Check fire box for accumulation of fuel on floor.

☐ 12. Throw switch to start burner. Purge furnace for one minute or as required.

☐ 13. Start fuel oil pump.

☐ 14. Light torch and insert in lighting off port.

☐ 15. Open atomizer valve slowly until flame is established (stand clear in case of flareback).

☐ 16. Remove torch. Extinguish in torch pot.

☐ 17. Regulate flame to warm up boiler slowly.

☐ 18. Regulate oil pressure valve to obtain proper amount of pressure.

☐ 19. After sufficient steam has blown from the air cock to expel all air from the drum, close air cock.

☐ 20. When steam pressure gage registers within 15 lbs below working pressure, lift safety valves with hand easing gear.

☐ 21. When working steam pressure is obtained, crack the main steam stop valve. Open slowly as pressure builds up in steam line.

☐ 22. Slowly open root valve to main steam line.

Operating

☐ Do not lose sight of the water gage glass on the boiler. If the water goes below safe operating level, secure the burner either by automatic or by manual control until the water returns to proper level.

Securing

☐ 1. Secure atomizer valve.
☐ 2. Throw burner switch to OFF.
☐ 3. Secure main steam stop valve.
☐ 4. Secure root valve to main steam line.
☐ 5. Raise water level in boiler to three-fourths of the glass by throwing the feed water regulator switch to MANUAL CONTROL.
☐ 6. Wipe up burner drip pan and wipe down pumps.

REMOVING BOILER FROM SERVICE

Boilers are removed from service when steam is not needed, or when repairs are necessary. Careful procedure in making removal and repairs will prevent quick temperature changes and damage to the equipment. Let us suppose that the boiler to be removed from service is a MULTIPLE-BURNER type burning heavy fuel oil. In making the removal, here are the steps to follow:

1. Blow the tubes with steam soot blowers, if soot blowers are installed.
2. Close the oil root valve and atomizing valve one by one, then disconnect the secondary air linkage and pull out the burner. (NOTE: After securing oil valves, run the blower long enough to make sure that the furnace is cleared of gases.)
3. Close up the furnace tightly to prevent cool air from getting into the heated interior. Close the stack damper, if installed, to retain the heat in the furnace.
4. Normally, cool the boiler slowly. If it must be repaired and returned to service in the shortest pos-

sible time, use forced cooling. Circulate air either by natural draft or by operating the induced-draft fan.

5. When the boiler is cool enough to enter, open the blowoff valves and allow the boiler to drain. As soon as it is emptied, close the blowoff valves.
6. If the boiler is to be taken out of service for a long period of time, clean the furnace, combustion chamber, and gas passages. Remove the handhole and manhole plates during the idle period, making sure the boiler is thoroughly dry; and if necessary, place trays of desiccant inside to absorb the moisture.

CLEANING AND REPAIRING OF FIRE SIDES

The boiler must always be kept in SPIC-AND-SPAN condition. A coating of soot of no more than one-sixteenth of an inch on boiler surfaces will cause at least a 5-percent fuel loss.

Fire sides should be kept scrupulously clean. Soot and other deposits seriously reduce boiler efficiency and contribute to the deterioration of the boiler. Soot is also a fire hazard.

Tubes are easier to clean while they are still hot, because the soot is still dry and powdery. All soot in the boiler must be removed thoroughly at each cleaning. Use steam blowers if the boiler has them. After the boiler has cooled, use wire brushes and scrapers.

The furnace and gas passages will probably require brushing about once each season. Before they can be brushed, however, the furnace must be secured and cooled.

BRICKWORK

Furnaces are built with high-grade, fire-resistant materials that can and do take a lot of punishment. Sooner or later, however, repairs become necessary. Furnace walls or floor may need repairing. You may get the job, and here is a suggested procedure.

First mix the mortar, using a Navy-recommended fire clay or fire cement, and fresh water. Don't add anything else. Make the mortar rather thin and without lumps.

Inspect the bricks for flaws and for evenness. Choose the best edge for the furnace side. Dip the brick in fresh water and allow the excess water to drip off.

Then dip one end and side of the brick into the mortar. In dipping the brick into the water and the mortar, use an edgewise motion to prevent air bubbles from being formed. Lift the brick from the mortar and allow the excess mortar to drip off. Do not place any mortar on the wall or brick with a trowel. The mortar sticking to the brick is all that is used.

If the mortar is too thick you will not obtain thin joints, which are essential to success. The mortar should be a little thinner than the usual wall plaster. You can feel the proper thickness with your hand. Some mortar will stick to your hand as you lift it away from the mortar. Add more clay or water as necessary, and stir the batch at frequent intervals to keep the mortar at the desired consistency.

Place the brick quickly in position in the wall and pound it in place with a wooden mallet until no more mortar can be forced out of the joints. With high-grade brick, joints can be made less than one thirty-second of an inch thick. Joints should never exceed one-sixteenth of an inch.

With a small trowel, fill in any unevenness in the furnace side of the seam and bead over the joints as shown in figure 13–1. Be sure that no edges of the brick are exposed. The wall should be laid up evenly and smoothly. Any excess mortar which protrudes from the joints should be smoothed off with a small trowel so that the corners of the brick are protected.

Allow the wall to dry for about 12 hours, with the burner shutters open to allow circulation of air. This is to permit the escape of some of the water added to the mortar. As soon thereafter as practicable, light the burner under the boiler and slowly bring the furnace up to

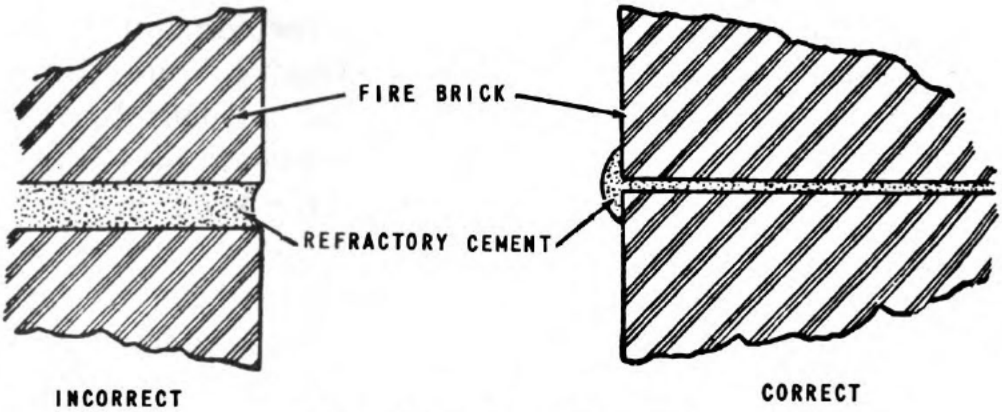


Figure 13–1.—Cementing brick.

operating temperature. This bonds the mortar to the adjacent brickwork.

Standard firebrick is generally used, but sometimes plastic firebrick is needed. Plastic firebrick is good for use in odd-shaped, circular, or small spaces; for repairing the burner openings, and for repairing brickwork.

Use the plastic firebrick just as it is received. Ram the chunks of plastic tightly into place in horizontal layers. Then hammer it at 45° angles with a wooden mallet. Using a 3/16-inch steel rod, make holes in the plastic section. These holes should extend through the plastic, and should be about 3 inches apart. Do not trowel the surface of the plastic section.

When inspecting the boiler you may find cracks or holes in the furnace lining. To make necessary repairs, mix some of the fire clay you used for brick mortar into a thin mixture. Use more mortar than you used for the brick mortar mix. Use a trowel to apply this wash.

CLEANING AND REPAIRING OF WATER SIDES

New boilers, or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound. New boilers must be washed out thoroughly.

Dissolve 5 pounds of caustic soda and 1½ pounds of sodium nitrate, or 10 pounds of trisodium phosphate, for each 1,000 gallons of water the boiler holds at steaming level. Put the mixture into the boiler. In case of multiple-drum boilers, divide the charge and put equal amounts in each of the lower drums.

Fill the boiler with hot feed water to the level of the bottom of the steam drum. Turn steam into the boiler through the usual boiling-out connections, or bottom blow, and allow the boiler to fill gradually to the top of the gage glass.

Steam pressure in the boiler should be kept between 5 and 10 pounds. The boiling out should continue for 48 hours.

Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should be cooled, washed out immediately, and given the usual mechanical cleaning.

As soon as men can work in the boilers, wire-brush the drums and ends of all tubes. Then clean the interior of all tubes, using the approved style of boiler tube cleaning brushes. There are three types of power-driven cleaners: (1) electric motor-driven, (2) pneumatic turbine-driven, and (3) hydraulic turbine-driven. A few tube cleaners are shown in figure 13–2.

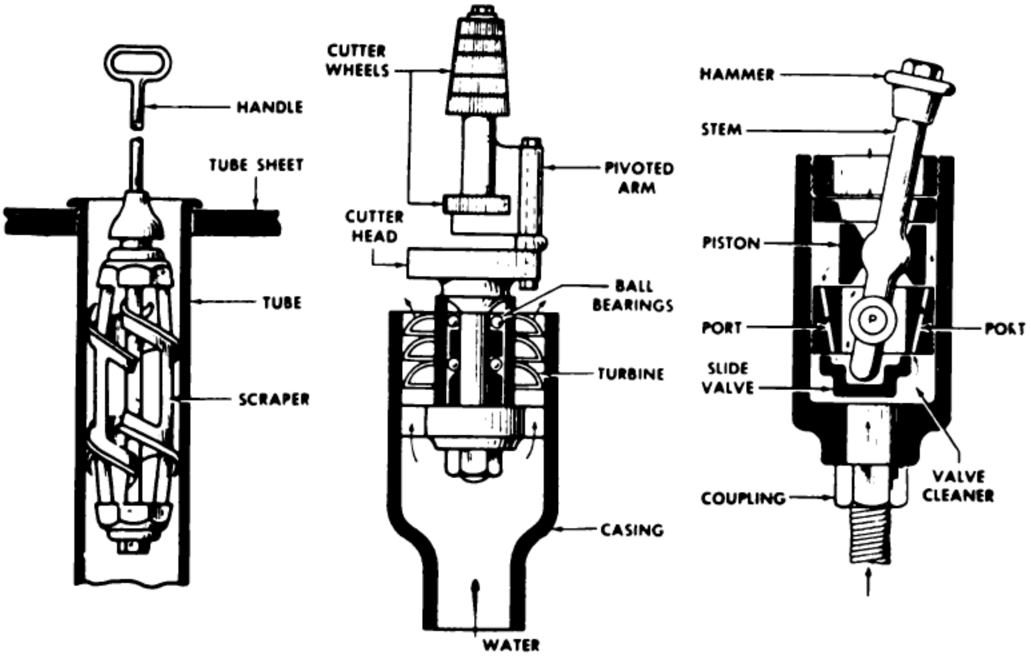


Figure 13–2.—Tube cleaners.

You operate all cleaners in the same way. Start the cleaner rotating and insert it in the tube. Pass it slowly along until it comes out the other end of the tube. Immediately reverse the direction and bring the cleaner back through the tube and withdraw it. Don't stop the cleaner at any point in the tube as it may cut through the tube. Also be careful not to extend the cleaner too far out at the end of the tube.

After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

REMOVING BOILER TUBES

Boiler tubes are made of a special steel designed to withstand a maximum pressure and temperature. The removal of defective tubes for renewal purposes is an important phase of your job as Utilities Man.

A recommended procedure for removing boiler tubes from a fire tube boiler consists of three steps:

FIRST: Using a flat chisel, split the ends in two places, about three-fourths of an inch apart, from the end of the tube up to the tube sheet.

SECOND: Force the $\frac{3}{4}$-inch piece up and into the center of the tube, using a blunt-nosed chisel, and exercising care to avoid damage to the tube sheet.

THIRD: Split the tube through and beyond the sheet, using a half-round chisel and being careful to avoid scoring the tube hole.

RENEWING BOILER TUBES

All badly warped tubes, tubes in which the belling is likely to give trouble, and tubes that leak after having been re-rolled must be replaced. Tubes should **NEVER** be straightened in place, as joints are liable to be strained, causing leaks and possible permanent injury to other parts of the boiler.

After removing the defective tubes—according to the 3-step procedure already described—you are ready to proceed with the replacement. Here's the procedure to follow:

1. Using emery cloth, thoroughly clean the hole in the tube sheet of all rust.

2. Clean the end of the boiler tube to be expanded in the tube sheet. Polish the outside surface of the tube. For a good polish job, first use a file to remove mill scale, then an emery cloth to remove file marks. If done right, the tube end should have a bright polish.

3. Insert the tube in the tube sheet. All tubes should extend through the tube hole three-sixteenths of an inch.

4. Clean the tube expander of all grit and put a few drops of oil on the rollers.

NOTE: There are various types of expanders, consisting essentially of three rollers, a body, and a mandrel. The thickness of the tube sheet should be considered in selecting an expander for a particular job. The rollers of the expander should be at least three-eighths of an inch longer than the thickness of the sheet if complete expansion of the tube is to be obtained.

5. Put the expander inside the tube end to be expanded, and expand the tube until it is tightly in place. A point to remember is that steel tubes should be expanded just enough to secure tightness, so that ample life may be left in the metal for future expanding should it be found necessary. The rolling should continue only until the rollers appear to operate evenly all around with sufficient pressure on the tool. The judgment of the operator must govern this point as no fixed amount of expanding can be specified in the case of repair work where tube holes vary slightly in size.

6. As a safeguard against pulling out, all tube ends of water-tube boilers are belled with a drift-type belling tool; the ends of fire-tube boilers are beaded with a beading tool. The belling or beading of tubes should not be more than one-eighth of an inch nor less than one-sixteenth of an inch increase over the outside diameter for all sizes of tubes.

STOPPING LEAKS IN BOILER SETTINGS

The boiler is an expensive item. Besides keeping it clean you will have to stop leaks, if the boiler is to have a normal useful life.

Immediate action is necessary when a leak appears. Leaks in boilers become larger if allowed to persist.

Cracks and leaks usually start around drums or other places where there is a strain on the setting (fig. 13–3). These cracks should be sealed immediately with a filler

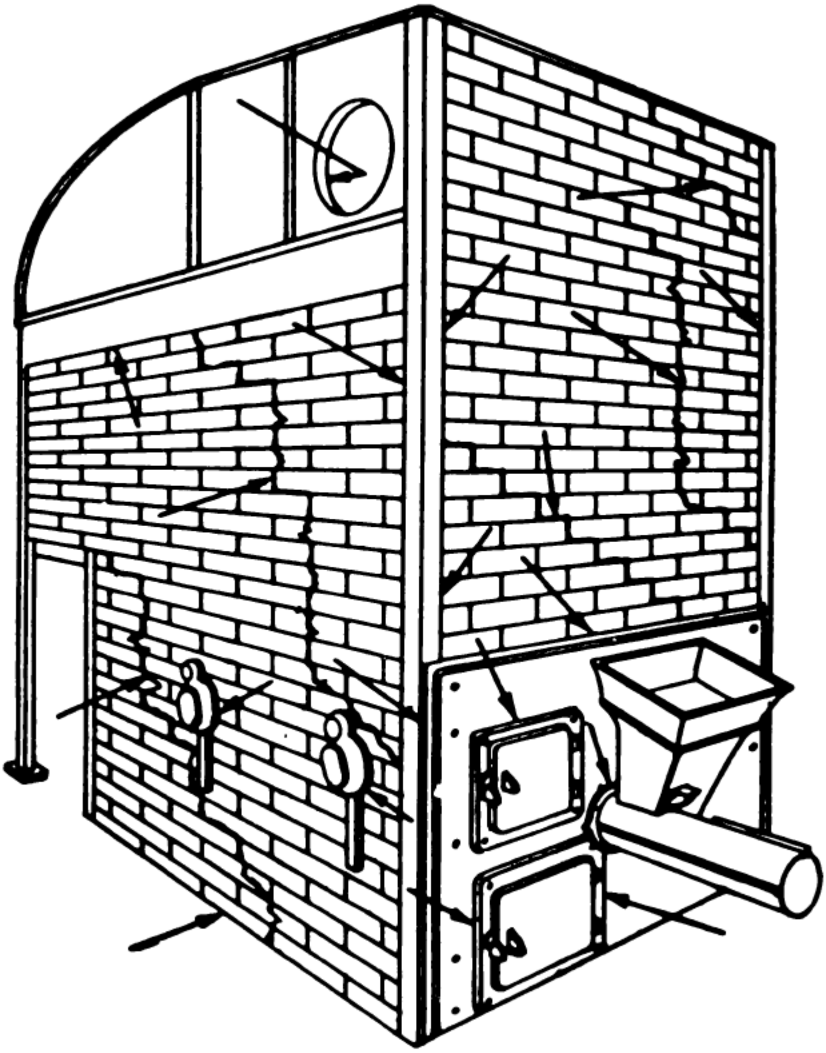


Figure 13–3.—Places on boiler setting to be checked for leaks.

material. Use only a Navy-approved joint sealing compound.

You may also find leaks around the anchor bolts used to support the furnace brickwork. These leaks may be reduced, if not stopped entirely, by making a small wick of the sealing compound and wrapping it around the anchor bolt shank between the furnace casing and the washer.

CONTROL OF WATER LEVEL

The boiler needs one pound of water to replace each pound of steam discharged from the boiler. Bear in mind that boiling water will have steam bubbles; hence, the water level may not be a true indication of the amount of water in the boiler. The rise and fall of the water level due to this bubbling is known as SWELL.

The need for proper control of water level can not be overemphasized. If the water level is too low, the boiler may be damaged by overheating, or it may explode. If the water level is too high, priming will occur, where some water is carried out with the steam, resulting in damage to engines and turbines and causing deposits to form in pipelines, valves, and other equipment. The gage glass, try cocks, high- and low-water alarms, and various water-indicating and recording gages serve a mighty useful purpose as guides in maintaining proper water level in the water column. Since the gage glass and try cocks seem to be the most reliable guides, they should be used as a final check on the water level.

Replacing Gage Glass

Because of the effect of the gage glass on safe operation, a special effort should be made to prevent defects which would cause a false water-level indication. A broken water gage should be replaced promptly. You may get the job. Here is how to do it.

Start by removing the packing nuts, packing, and pieces of broken glass. Then insert the new glass and packing, and tighten the packing nuts. Now turn on the upper steam valve and heat the new glass uniformly. As a safety precaution always wear goggles, and use a wire mesh or canvas screen when putting pressure on the gage glass.

CARE OF FEED-WATER REGULATORS

Proper control of water level requires, also, that the feed-water regulator be maintained in top operating condition. Here are a few pointers applicable to the regulators illustrated in figures 12–11 and 12–12.

In case of a considerable change in the water level from its normal position, make sure you adjust the bypass to manual operation and check promptly for the source of failure. If leaks develop around packed stems, you will want to see that they are stopped immediately. Of course, if the boiler is off the line, it is important that you close the hand valve in the feed line. Bear in mind that the regulator is not designed for use as a stop valve. About once every three months you will probably be called on to assist in blowing down the steam and water connections separately.

CARE OF VALVES

Valves deserve special care and attention if they are to serve their intended purpose. In this section we will outline some of the general instructions concerning several different types of valves. First, we should remind you that allowance must be made for variations among activities in the type and frequency of valve inspections, as well as servicing requirements. Therefore, instructions issued by your particular activity should be followed when they differ from those outlined here.

Types of valves which you may be responsible for helping service and maintain, at regular intervals, include (1) stop valves of the globe or gate type; and (2) stop-and-check valves, which combine in one unit an angle or stop valve of the globe type and a check valve. At least once every three months, any of these valves which have not been operated for some time should be operated in order to prevent sticking. Make sure that you also check for leaks and lubricate the exposed threads and gearing of the valve stem.

You will need to loosen and lift the packing follower about once every three months—or more often. Lubricate the packing with graphite-bearing oil or graphite-bearing grease. Replace the packing followers and tighten sufficiently to ensure against leaks.

Now let us consider briefly the kind of care required for BLOWOFF VALVES. These valves should be opened at least once a day. The amount and frequency of blowing down will depend on a chemical analysis of the water in the boiler concerned.

On a quarterly basis, inspect the blowoff valves at the time the boiler is washed out and when an internal inspection is made. Check the valves for leaks, and inspect the pipe and fittings between the blowoff valves and the boilers. If repairs are needed, see that they are made promptly.

In making a quarterly check on the blowoff valves, do not overlook the insulation, bearing in mind that it should be kept dry. Another item to include is the discharge piping leading from the valves. Make sure the discharge piping is not mounted so rigidly that proper expansion and contraction will be affected.

Too strong emphasis can not be placed on the need for keeping SAFETY VALVES in top working order. Two important daily requirements deserving careful attention are:

FIRST, make sure that no dirt, scale, or other foreign matter is permitted to accumulate between the coils of the safety-valve spring.

SECOND, note the popping pressure when the safety valve pops normally. A pressure exceeding 5 psi either above or below the specified popping pressure calls for a test of the pressure gage. If a test shows the gage to be correct, let the chief in charge know right away that the valve has to be reset.

You may be called on to make a thorough test about once each quarter on the operating condition of each safety valve. In making the test, gently raise the valves off their seat by hand, first making sure there is sufficient pressure (75 percent of normal working pressure) to prevent straining the easing gear, as well as to blow the seat clean of dirt and scale. If defects such as leaking, simmering, or chattering are found, see that they are corrected at once.

STEAM TRAP MAINTENANCE

Proper maintenance is essential to efficient operation of steam traps. To ensure that traps receive proper care and upkeep, maintenance inspections should be made at regular intervals. Here are some of the things you should look for, and various repairs or adjustments you may have to make, in conducting a maintenance inspection of steam traps.

All steam traps should be disassembled, cleaned, and checked for proper operation of the mechanism, scored valve seats and disks, and other defects. In addition, make sure you dismantle, clean, and check the condition of strainers, as well as the inlet, discharge, and bypass valves. See that any scored or leaking valve seats and disks are ground-in or replaced. Also, if the linkage mechanism is found to be defective, make sure it is repaired or replaced, as necessary, to avoid any binding or jamming and to ensure smooth operation.

In addition to general maintenance, there are certain items which deserve special attention in different types of steam traps. If it is a FLOAT TRAP, for instance, you will want to examine the float for leaks or deterioration. If either condition exists, the float should be replaced.

The trap bucket on a BUCKET TRAP must also be checked for leaks or deterioration; replace the old bucket where necessary. If it is an inverted bucket, clean the air vent hole in the top of the bucket, making sure that no obstruction remains that would hamper its operation. See that integral check valves (if installed) are in a tight but freely operative condition.

On an IMPULSE TRAP, any obstructing material in the orifice in the valve disk-control piston assembly should be removed completely.

With a BIMETALLIC-ELEMENT type of trap, it is important that the valve stem be adjusted to provide unrestricted flow to condensate and tight closing on steam. Best results are obtained when a check on the performance of the trap is made during actual operation. A visual check can be made by looking through the glass window provided on most traps of this type.

CARE OF FANS

The forced-draft fan should be checked daily to prevent accumulation of dust in or around the fan. Keep the fan clean! Also, check daily on the sound of the fan; if it is not normal, report the matter promptly to your supervisor.

A daily check should also be made to ensure adequate lubrication of the fan. The temperature is another item which should not be overlooked. This you can test by feel. In case of excessive temperature, notify your supervisor immediately.

Because induced-draft fans are exposed to hot dirty gases, they must be observed closely to prevent operating difficulty. Taking proper care of the fan requires that attention be given DAILY to ensure that the following conditions are properly met:

(1) Bearings are kept cool and well lubricated.
(2) Fan is kept clean. Also, see that any change from the normal in sound is reported promptly to your supervisor.

OIL BURNERS: TROUBLESHOOTING AND SERVICING

Among the major duties of the UT 3 or 2 are those involving troubleshooting and servicing of oil burners. To keep the burner in good operating condition you must be able to recognize the symptoms of various types of trouble and must know how to make various service and maintenance adjustments to the burner.

Before getting into this discussion on troubleshooting and servicing of oil burners, let us point out that the type of burner with which we are primarily concerned is a SMALL, DOMESTIC-TYPE, AUTOMATICALLY OPERATED OIL BURNER FOR LIGHT FUELS. Bear in mind, also, that some variation can be expected in the operation and maintenance of different makes and models of oil burner. It is important, therefore, that you familiarize yourself with the procedures set forth in the manufacturer's instruction manual furnished with the unit you are using. Keep the manual handy as a ready reference, and use it as a guide in locating the source of trouble and for making operating and service adjustments necessary to correct defects in the burner.

In operating a boiler, it will pay you to be constantly on the watch for signs of trouble. If you notice the furnace PULSATING ON STARTING, STOPPING, OR DURING OPERATION, you will want to check all the nozzle-electrode assembly adjustments and blast tubes in relation to each other. Make sure the draft is proper and that there is no downdraft. If the draft is not strong enough, correct by changing the setting on the draft regulator. If necessary, check the chimney for leaks causing poor draft.

If the pulsating is caused by a defective nozzle, the remedy, of course, is to put on a new one. You will want, also, to be sure that air is out of the line between the fuel unit and nozzle. Air trapped here compresses during burner operation and expands when the burner stops. This causes oil to squirt at the nozzle and a bubble to form when the burner shuts down. It is best to delay making final adjustments to a new burner until several days after installation. This often allows time for removal of trapped air.

In cleaning the nozzle, remember that it is a delicate device and must be handled with care. It should be cleaned only in the shop on a clean workbench. To cut grease or gum, use kerosene or safety solvent. To blow dirt out of the nozzle, use compressed air. Goggles should be worn to protect the eyes when using compressed air. Never use a metal needle to clean the orifice. Instead, sharpen the end of a match, or use a brush bristle. The socket wrench is the correct tool to use in turning the nozzle. You will want to make sure the nozzle seat is clean. To ensure a tight oil seal, back the bottom off and retighten several times. However, do not get it too tight, or the brass threads may strip and make it difficult to remove.

If the burner has a RAW, STRINGY FLAME, check the air adjustment to make sure it is not open too wide. Too much air makes a poor fire and causes the surplus raw oil to soak into the firebrick. The nozzle is another item to check in locating the source of trouble. If the nozzle is partially plugged, replace it with a new one. A raw, stringy flame is sometimes due to air in the pump. When this seems to be the trouble, open the petcock on the pressure gage to purge the air from the system.

In making a troubleshooting inspection, always check the IGNITION POINTS to make sure there is no accumulation of carbon on them. If you find carbon on the ignition points, first ascertain whether the nozzle is in good condition. If so, move the ignition points up if in spray. In checking the nozzle, make sure it is tight in its holder. If loose, oil is likely to leak out and cause an accumulation of carbon on the electrodes. It is also a good idea to check on the shut-down of the burner to determine whether there is a clean cutoff of oil by the pressure-regulating valve. After the burner is stopped, there should be NO DRIBBLE of oil into the furnace. This condition is to be avoided as it is likely to cause late ignition.

Another common failure to expect in the oil burner is NOISE IN THE OIL PUMP. The noise usually is caused by air in the oil lines. Therefore, first purge the air from the oil lines. To do this, simply loosen the vent plug where the pressure gage is attached. When this does not correct the trouble, a plugged strainer or condensed water in the oil tank are the two most likely suspects. The noise here results from the excessive suction which these conditions exert on the oil line. As a remedy, clean the strainer in the pump and, also, clean the strainer on the fuel line. Also, check for leaks in the suction line. Leaks in overhead piping, above the liquid level in the storage tank, will permit air to enter the oil line.

A point to note is that with some very light oils, an overhead pipeline allows air in the oil to settle out and collect in bubbles. Air can then come through and obstruct pipe action. Two-pipe systems minimize this danger.

If the trouble is FREQUENT RECYCLING, check to make sure the heating element in the room thermostat is screwed in tight. With that done, check for reverse wiring or incorrect splicing, as well as for reversed wiring at the flame-failure device. Then check the thermostat for proper adjustment.

In locating the source of frequent recycling, do not overlook the nozzle. On this score, remember that if the nozzle is too large for the unit, it may cause the heat to build up too rapidly. When the trouble lies in the nozzle, the solution, of course, is to replace it with one of the proper size.

If the stack control throws the burner into safety SHUTDOWN, the reason may be due to a low-voltage night power supply. This calls for a check with a recording voltmeter for at least 24 hours, preferably longer. In addition, check the wiring polarity. This is important because if connections are reversed, or if hot line is where ground should be, there is sometimes enough leakage through the control to cause a safety shutdown.

If NO OIL is obtained at the NOZZLE, here is how to go about locating the source of trouble:

—Check the fuel tank to see if you have an adequate supply of fuel

—Check the nozzle to make sure it is not plugged

—Inspect the suction line for signs of leaking

—Test to determine whether the pump shaft turns

—Look for leaks at the strainer gasket and pump shaft seal.

You may encounter a situation where none of these checks disclose the source of the trouble. In this event, loosen the vent plug in the fuel unit (pump) and run the burner to see if fuel flows as far as the fuel unit. If it does, there is something wrong with the unit.

HYDROSTATIC TESTS

Hydrostatic tests are made to prove either the TIGHTNESS of all parts of the boiler or the STRENGTH of the boiler and its parts.

In preparing the boiler for a test, rinse it out with fresh water. Then check carefully to see that there is no loose scale or tools left in any part of the boiler. Close all openings and gag (clamp down) all safety valves. Close all connections on the boiler except the air cocks, water gages, pressure gage, and the valves of the line through which pressure is to be applied.

Completely fill the boiler with fresh water and close the air cocks. Apply a water pressure of 1½ times the working pressure of the boiler. Maintain this pressure until the boiler and fittings are inspected. After leaks are repaired, apply the same pressure and close the valve in the pressure line.

If the boiler and fittings are tight, the pressure should not drop more than 1.5 percent in 4 hours. If loss is higher, find the leaks and make the necessary repairs.

Following all hydrostatic tests, steam pressure is raised to lift the safety valves. This is to test and set the safety valves and to definitely determine the fitness of the boiler for use.

BOILER WATER TESTS

Boiler water must be treated with chemicals to prevent the formation of scale on the internal surface of the boiler, and to prevent deterioration of the boiler metal by corrosion. Testing of boiler water is necessary to determine whether the amount of chemical residuals required to maintain clean boiler surfaces is present. As a Utilities Man you should be able to make various kinds of boiler water tests. (See fig. 13–4.) The procedure for a few types of tests, which you may be called on to make, will be given here; for instance, tests for hardness, phosphate, tannin, caustic alkalinity (with and without tannin), sodium sulfite, and *p*H. A test kit is provided for each test. The kit for a particular test will contain the equipment and materials required to make the test.

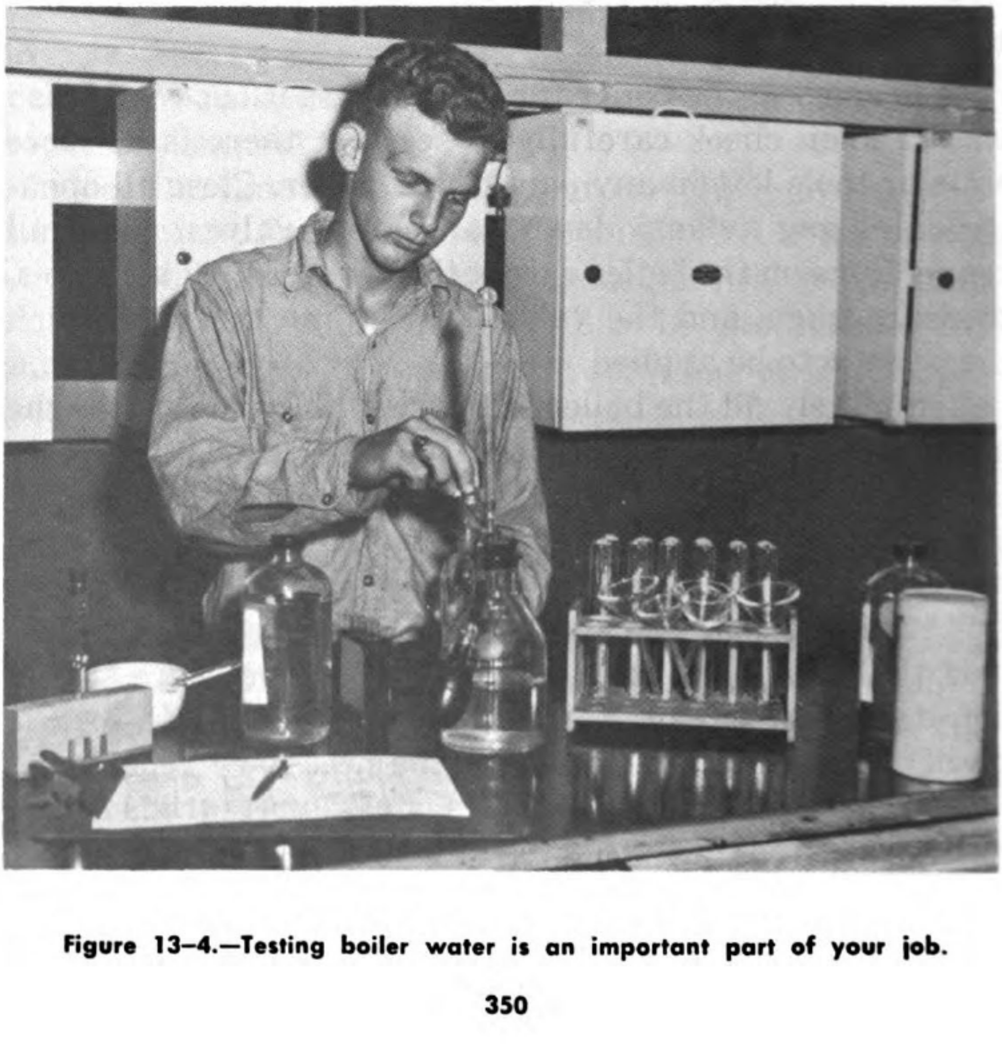


Figure 13–4.—Testing boiler water is an important part of your job.

Before proceeding, here is a brief word of caution which applies to each test that will be discussed: IF THE TESTING PROCEDURE OF THE EQUIPMENT AND/OR REAGENT SUPPLIER DIFFERS FROM THAT PRESCRIBED IN THIS TEXT, THE SUPPLIER'S PROCEDURE SHOULD BE USED.

Test for Hardness

Boilers operating at pressures of 15 psi and less are normally used for space heating and hot water generation. Practically all the condensate is returned to the plant. Only a small amount of makeup is required, and secondary feedwater treatment usually is sufficient. When appreciable quantities of steam are used in process work and not returned as condensate to the plant, the problem of scaling and corrosion arises, and more complete treatment of feedwater must be considered.

The ideal water for boilers is one that does not form scale or deposits, that does not pit feedwater system and boiler surfaces, and does not generate appreciable CO_2 in steam. However, such a raw makeup water is impossible to obtain in the natural state from wells or surface sources. It is necessary, therefore, to treat it to the extent that treatment can be justified economically in terms of advantage gained.

Feedwater of 20 to 25 ppm hardness as $CaCO_3$ need not be treated externally for reduction of hardness if sufficient alkalinity is present to precipitate the hardness in the boiler as $CaCO_3$, or if hardness reducers such as phosphates are introduced to combine with and precipitate the hardness. Precipitation of this hardness in a low- or medium-pressure boiler generally will not cause wasteful blowdown. When the mixture of condensate and makeup in a medium-pressure steam plant possesses a hardness greater than 20 to 25 ppm as $CaCO_3$, the hardness should be reduced to 0 to 2 ppm as $CaCO_3$.

Feedwater of a hardness in excess of 2 ppm as $CaCO_3$ should be treated to bring it within the range of 0 to 2 ppm as $CaCO_3$. This small remaining hardness after external treatment can be precipitated in the boiler by secondary treatment and removed by continuous blowoff equipment.

The test for hardness, as presented here, employs the Colorimetric Titration Method. This test is based on the determination of the total calcium and magnesium content of a sample by titration with a sequestering agent in the presence of an organic dye sensitive to calcium and magnesium ions. The end point is a color change from red to blue. It occurs when all the calcium and magnesium ions are sequestered.

The following equipment is used in making this test:

One 25-ml burette, automatic, complete
One 210-ml casserole, porcelain
One 50-ml cylinder, graduated
One stirring rod, glass.

The reagents are:

Hardness indicator
Hardness buffer
Hardness titrating solution.

To make the test, start by measuring 50 ml of the sample in the graduated cylinder and transfer it to the casserole. With the calibrated dropper, now add 0.5 ml of the hardness buffer reagent to the sample, and stir. Then add 4 to 6 drops of hardness indicator. If hardness is present, the sample will turn red. Add the hardness titrating solution slowly from the burette, with continued stirring. When approaching the end point, the sample begins to show some blue coloration, but a definite reddish tinge can still be seen. The end point is the final discharge of the reddish tinge. More hardness titrate solution does not produce further color change.

In using this procedure, the hardness titrating solution must be added slowly because the end point is sharp and rapid. For routine hardness determination it is suggested that 50 ml of the sample be measured, but only approximately 40 to 45 ml be added to the casserole at the start of the test. The hardness buffer reagent and the hardness indicator should then be added as directed, and the mixture titrated rapidly to the end point. The remaining portion of the sample should then be added. The hardness present in the remainder of the sample turns the contents of the casserole red again. Titrating is continued slowly until the final end point is reached. A record should be kept of the total milliliters of hardness titrating solution used.

To calculate the results, in ppm hardness, use the following equation:

$$\text{ppm hardness as CaCO}_3 = \frac{\text{ml titrating solution} \times 1{,}000}{\text{ml sample}}$$

Using a 50-ml sample, the hardness in ppm as $CaCO_3$ is equal to the ml of titrating solution employed, multiplied by 20.

Test for Phosphate

This is a colorimetric test for phosphate, employing a decolorizing carbon for removal of tannin. Carbon absorbs the tannin, and the carbon and tannin are then filtered out. When tannin is not present, carbon improves the test for residual phosphate by making the tricalcium phosphate sludge more filterable.

The equipment required for the phosphate test includes:

One phosphate color comparator block of two standards—30 ppm and 60 ppm of phosphate as PO_4. (The Taylor high-phosphate slide comparator may be used instead.)
Four combination comparator mixing tubes, each marked 5, 15, and 17.5 ml, with stoppers
One filter funnel, 65-mm diameter
One package filter paper, 11-cm diameter
One 20-ml bottle
One ½-ml dropper
One ¼-teaspoon measuring spoon
Two plain test tubes, 22 mm x 175 mm (about 50 ml)

Two rubber stoppers, No. 3 flask

One 250-ml glass-stoppered bottle, labeled Comparator Molybdate Reagent.

The reagents you will need are:

One 32-oz comparator molybdate

One 2-oz concentrated stannous chloride

One 32-oz standard phosphate test solution (45 ppm of phosphate, PO_4)

One lb decolorizing carbon. (This is a special grade of decolorizing carbon that has been tested to make sure it does not affect the phosphate concentration in the sample.)

For test purposes, the stannous chloride is supplied in concentrated form. The reagent must be diluted and should be prepared from the concentrated stannous chloride on the day it is to be used, because the diluted solution deteriorates too rapidly for supply by a central laboratory. If not fresh, dilute stannous chloride gives low test results. Concentrated stannous chloride also deteriorates in time and should not be used if more than two months old. Dilute stannous chloride is made by the following method:

(1) Fill the ½-ml dropper up to the mark with the concentrated stannous chloride.

(2) Transfer it to a clean 20-ml bottle.

(3) Add distilled water up to the shoulder of the bottle, then stopper and mix by shaking.

Any dilute stannous chloride not used the day it is made should be discarded.

To make the test for phosphate, here is the procedure to follow:

(1) Without disturbing any settled sludge, transfer sufficient of the sample to the test tube to fill it about half full.

(2) Add ¼ teaspoonful of decolorizing carbon. Stopper the tube and shake vigorously for about 1 minute. The carbon absorbs the tannin so that it can be filtered out.

(3) Fold a filter paper and place it in the filter funnel. Do not wet down the filter paper with water. Filter the shaken sample, using a combination mixing tube as a receiver. The carbon absorbs tannin, and the tannin and sludge present are filtered out more readily. Avoid jiggling the funnel, as unfiltered boiler water may overflow the edge of the filter paper into the tube. It may be necessary to provide a support for the funnel. Filtering is slow because of the action of carbon.

(4) After 5 ml of sample has filtered through, as indicated by the level in the tube, discard it. Continue filtering to bring the level in the test tube again up to the 5 ml mark. The sample should come through clear and free, or nearly free, of any color resulting from tannin. If not nearly free of tannin color, repeat the test using ½ teaspoon of carbon, adding it in two ¼-teaspoon portions, shaking it for a minute after each addition.

(5) Add comparator molybdate reagent to bring the level up to the second mark (15 ml). Stopper and mix by inverting the tube several times.

(6) Add fresh dilute stannous chloride up to the third mark (17.5 ml). Stopper and mix by inverting. If phosphate is present, the solution in the mixing tube turns blue.

(7) Place the tube in the comparator block. Compare the color of the solution in the tube with the standard colors of the phosphate color block. Colors between the two standard colors may be estimated. Take the reading within 1 minute after adding the stannous chloride, because the color shortly fades.

(8) Record the results as LOW, if below 30 ppm; HIGH, if above 60 ppm; or OK, if between 30 and 60 ppm.

Tannin Test

The purpose of the TANNIN TEST is to determine the amount of tannin in the boiler water. Tannin is used to hold sludge in suspension. In treating boiler water with tannin, the dosage can be controlled by the depth of brown formed in the boiler water by the tannin. To estimate the depth of the color, which is necessary in adjusting tannin dosages, a sample of the boiler water is compared with a series of brown color standards of successively increased depths of color. A tannin color comparator, which is used for the comparison, has five glass color standards: No. 1, very light; No. 2, light; No. 3, medium; No. 4, dark; and No. 5, very dark.

The kit for the tannin test contains:

One tannin color comparator
Two square tubes, 13 mm viewing depth
One plain test tube, 22 mm x 175 mm
One filter funnel, 65 mm x 65 mm
One package of filter paper, 11-cm diameter.

In making this test, first fill a plain test tube almost to the top with cool boiler water. Then place a square test tube in the slot of the comparator, and insert the filter funnel in it. Fold a filter paper and place it in the funnel without wetting it down. Filter water from the plain test tube into the square tube until the tube is nearly full.

Remove the square tube from the comparator and hold it up to a good source of natural light. Note the appearance of the filtered boiler water. It should be free of suspended solids and sludge. If it is not, refilter the sample, using the same funnel and filter paper. Repeat, using double filter paper if necessary, until the sample does come through free of suspended solids and sludge.

To complete the test, place the square tube of filtered sample in the middle slot of the comparator. Then compare the color of the sample with the five color standards, viewing it against a good source of natural light. The color standard most closely matching the color of the filtered sample gives the tannin concentration of the boiler water. For a number of boiler water conditions, the tannin dosage is usually satisfactory if it maintains a medium (No. 3) tannin color.

Test for Caustic Alkalinity (OH) Without Tannin

The boiler water sample for this test is collected at a temperature of 70° F, or below.

The equipment required is as follows:

- Two 8-in. droppers with bulbs
- Two 250-ml glass-stoppered bottles, labeled Causticity No. 1 and Causticity No. 2
- Four marked test tubes, 22 mm x 185 mm
- Three plain test tubes, 22 mm x 175 mm
- Three rubber stoppers, No. 2
- One 14-in. test-tube brush
- On test-tube clamp
- Two 9-in. stirring rods
- One 1-oz indicator dropping bottle for phenolphthalein
- One test tube rack.

The following reagents also are required:

- One 24-oz bottle causticity reagent No. 1
- One 24-oz bottle causticity reagent No. 2
- One 4-oz bottle of phenolphthalein indicator.

Here are the steps to follow in conducting a test for causticity when tannin IS NOT used. But first, as a word of caution: AVOID EXPOSURE OF THE SAMPLE TO THE AIR AS MUCH AS POSSIBLE TO MINIMIZE ABSORPTION OF CO_2.

(1) Without disturbing any settled sludge, fill a marked test tube exactly to the first mark (25 ml) with some of the original boiler water sample.

(2) Shake causticity reagent No. 1 (barium chloride solution saturated with phenolphthalein) thoroughly and add enough to the graduated tube to bring the level exactly to the second, or long, mark (30 ml). Stir the solution with the stirring rod, which must be kept clean and reserved for the causticity test only. If the mixture remains colorless or does not turn pink, the causticity in the boiler water is zero. In this case the test is finished.

(3) If the mixture turns pink, causticity is present. (If the pink color is not very deep, intensify it by adding two

drops of phenolphthalein indicator to the mixture in the tube.) Add causticity reagent No. 2 (standard 1/30 normal acid), using the dropper, which must be kept clean and reserved for the causticity test only. Causticity reagent No. 2 is sucked from the reagent bottle into the dropper by its rubber bulb and added, drop by drop, to the test tube. After each addition, stir the mixture with a stirring rod. After sufficient reagent has been added, the pink color disappears, the change point usually being very sharp. As soon as the pink color just fades out, stop adding reagent.

(4) The amount of causticity reagent No. 2 required to make the pink color disappear indicates the concentration of hydroxide (OH) or causticity in the boiler water. The amount of reagent used is shown by the marks on the test tube above the long mark (30 ml). The distance between any two marks on the test tube equals 5 ml, and readings less than 5 ml can be estimated. For example, if only 3/5 the distance between the long mark and the next mark above was filled, then 3 ml were added. If the distance filled was past one mark plus 3/5 the distance to the next, then 5 + 3 = 8 ml were used. To obtain the actual ppm of hydroxide or causticity shown by the test, multiply the number of ml by 23. Thus, for 8 ml of causticity reagent No. 2, there are 8 × 23 = 184 ppm hydroxide or causticity in the water.

(5) Record the results of the test as zero or in ppm, as the case may be.

Test for Caustic Alkalinity (OH) With Tannin

For this test, it is desirable to start with a warm sample of about 160° F. It may be reheated by placing the sample-collecting container in a stream of hot boiler water drawn through the boiler water cooler connection.

In a test for causticity when tannin is used, make sure you observe the following precaution as carefully as when tannin IS NOT used: AVOID EXPOSURE OF THE SAMPLE TO

THE AIR AS MUCH AS POSSIBLE TO MINIMIZE ABSORPTION OF CO_2.

The equipment and reagents required for this test are the same as those listed in the preceding section, where tannin was not used.

The procedure for conducting a test for causticity, when tannin is used, can be broken down into the following steps:

(1) Fill two test tubes to the first mark (25 ml) with some of the original boiler water sample, taking care not to disturb the settled sludge in the container. (It is important that as little sludge as possible be transferred from the sample-collecting container to the test tubes.)

(2) Shake causticity reagent No. 1 thoroughly and add enough to each of the two marked tubes to bring the levels up to the second, or long, mark (30 ml). Stir both with the stirring rod, which must be kept clean and reserved for the causticity test only. Stopper both tubes and let them stand until any sludge formed has settled to the bottom. The sludge carries down with it much of the tannin or other colored matter in the solution; settling takes a few minutes if the sample is warm. Without disturbing the sludge at the bottom, pour enough solution from the tubes into the third marked tube to fill it to the second, or long, mark. Discard the mixture left in the first two. If the sample in the third is still warm, cool it by letting cold water run on the outside of the tube. It is sometimes possible to intensify the pink color by adding two drops of phenolphthalein from the indicator dropping bottle to the sample in the tube. Stir the solution. If it is not pink, the causticity in the boiler water is zero.

(3) In that case, the test is finished. But if the mixture turns pink, proceed in the same manner as directed in steps (3), (4), and (5) when NO TANNIN is used.

Perhaps a brief explanation should be given of an ALTERNATE PROCEDURE which can be followed in making the test for causticity when tannin is used. In this procedure any glass container, such as a large test tube or graduated cylinder, marked for 50 or 60 ml can be used instead of two standard marked test tubes used in steps (1) and (2) above. With the large test tube or graduated cylinder, the warm (160° F) sample is added up to the 50-ml mark and causticity reagent No. 1 up to the 60-ml mark. Stir the mixture and stopper the tube or graduate. After the sludge settles, pour off enough of the solution into one of the standard marked test tubes to fill it to the long mark (30 ml). If the sample is warm, cool it by letting cold water run on the outside of the tube. The pink color may be intensified by adding two drops of phenolphthalein. If the solution is not pink, the causticity in the boiler water is zero. But if it turns pink, proceed in the same manner as (3), (4), and (5) when NO TANNIN is used.

Test for Sodium Sulfite

The sample for this test should be cooled to 70° F, or below, and exposed to the air as little as possible, because oxygen in the air combines with sodium sulfite in the sample and causes low readings. It is desirable, therefore, to collect a separate sample, using the boiler water sample cooler, with the line reaching to the bottom of the sampling bottle. The boiler water should be allowed to run until a few bottlefuls overflow to waste.

The equipment necessary to make the sodium sulfite test includes these items:

Two marked test tubes
Two plain test tubes
One stopper for plain test tube
One stirring rod
One 7-in. dropper
One 1/4 teaspoon
One 50-ml beaker
One 150-ml beaker
One 30-ml acid dropping bottle, with dropper marked at 1/2 ml for hydrochloric acid 3N

One 30-ml starch dropping bottle, with dropper marked at ½ ml for starch indicator.

The reagents required are as follows:

One 2-oz bottle of potato, or arrowroot, starch
One 8-ml vial of thymol
One 24-oz bottle of hydrochloric acid 3N
One 1-pt amber bottle of standard potassium iodate-iodide reagent.

The starch indicator for this test must be prepared locally. Here is the procedure to follow for good results.

(1) Measure out a level ¼ teaspoonful of potato or arrowroot starch and transfer it to the 50-ml beaker.

(2) Add a few milliliters of distilled water and stir the starch into a thin paste, using the end of the stirring rod.

(3) Put 50 ml of distilled water into the 150-ml beaker. (It is convenient in this step to have the 150-ml beaker marked at the point where it holds 50 ml, or one of the marked test tubes can be used by filling it with distilled water to the fourth mark above the long mark.)

(4) Bring the water in the 150-ml beaker to a boil by any convenient method.

(5) Remove the source of heat and immediately pour the starch paste into the boiling water while stirring the solution.

(6) Put a crystal of thymol into the starch solution and stir. After the solution has cooled, pour off any scum on the surface and transfer 30 ml to the indicator dropping bottle.

The starch solution loses its sensitivity as an indicator after a time. Addition of the thymol preserves it for about two weeks. The starch should be dated when prepared.

In making the sodium sulfite test, proceed as follows:

(1) Transfer 1 ml of hydrochloric acid 3N to a clean, marked test tube by measuring out two ½-ml portions with the dropper of the acid dropping bottle.

(2) From the starch dropping bottle, transfer ½ ml of starch to the marked test tube.

(3) Without disturbing any settled sludge in the sample, pour enough sample into the marked test tube to bring the level up to the first mark (25 ml). Stir the mixture in the tube with the plunger end of the stirring rod.

(4) To add the standard potassium iodate-iodide reagent to the mixture in the marked test tube, it is convenient to have the marked test tube supported and the stirring rod placed in the tube, so that the reagent can be added with one hand while the mixture is stirred with the other. Fill the 7-in. dropper with standard potassium iodate-iodide reagent from the stock bottle by sucking it up with the rubber bulb. (The dropper must be kept clean and reserved for this test only.)

(5) Add the reagent to the mixture in the marked test tube, one drop at a time, counting the number of drops and stirring after each is added until a permanent blue color, which is not removed by stirring, is obtained. The standard iodate-iodide reagent reacts with sodium sulfite in the mixture, and formation of the permanent blue color from the action of excess reagent with the starch shows that all the sodium sulfite in the mixture has been consumed by the iodate-iodide reagent.

(6) Each drop of iodate-iodide reagent used (except the last one) indicates 5 ppm of sodium sulfite in the boiler water sample. To figure the concentration of sodium sulfite in the boiler water, multiply the total number of drops of the standard iodate-iodide reagent used, less one, by 5.

(7) Record the results of the test as ppm.

Test for *p*H

The value of *p*H indicates the degree of acidity or alkalinity of a sample. A *p*H of 7.0 represents the neutral point, lesser values denote acidity, and greater values alkalinity. The test is made as soon as possible after taking the sample. Avoid exposure to air as much as possible to minimize absorption of CO_2.

Equipment used in making the *p*H test of boiler water includes:

- Two vials indicator paper, hydrions *p*H 10 to 12
- Two vials indicator paper, hydrions C *p*H 11 to 12
- One 50-ml beaker
- One 2-oz bottle

In conducting the test for *p*H of boiler water, remove a strip of *p*H 10-to-12 indicator paper from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds, then remove it. If the sample does not change the color of the paper, or colors it yellow or very light orange, the *p*H of the sample is too low and the test is finished. If the paper turns orange or red, the *p*H is either satisfactory or too high.

In that case, remove a strip of paper of *p*H 11 to 12 from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds, then remove it. If the sample does not change the color of the paper, or colors it a light blue, the *p*H is satisfactory. If the paper turns deep blue, the *p*H is higher than necessary.

pH of Treated Condensate

In making a test for *p*H of treated condensate, take the sample from a point in the return piping near which condensation takes place, such as after a trap, or preferably where return-line corrosion is known to occur. The sample must be representative of water flowing in the return lines. Water taken from the return tank, especially of large installations, generally shows a higher *p*H. A sample should not be taken from a collecting tank if other water, such as makeup, is received in the tank.

The equipment required for this test includes:

- One 4-oz brown bottle of condensate *p*H indicator
- One 1-oz indicator bottle, with dropper marked at 0.5 ml
- One 100-ml beaker, marked at 50 ml
- One 9-in. stirring rod, glass.

In making a test for *p*H of treated condensate, proceed as follows:

- —Pour a freshly drawn sample into the testing beaker until it is filled to the 50-ml mark. Cooling of the sample is not necessary
- —Transfer ½ ml of indicator solution to the 50-ml testing beaker, using the marked dropper. Stir the solution in the beaker. The resulting color indicates the *p*H
- —If the sample is now colored green, the return water is acid; if light pink, the *p*H is satisfactory; and if red or purple, the *p*H is higher than necessary.

Other Tests

In addition to the tests described in previous sections, there are a number of others which you may be called on to make. These include tests for total dissolved solids; free carbon dioxide; dissolved oxygen; silica; and chlorides. For information on how to make these tests, refer to chapter 4 of *Power Plant Water Conditioning*, NavDocks TP–Pu–3.

As a final word of caution, remember that if the testing procedure of the equipment and/or reagent supplier differs from that prescribed in this text or in TP–Pu–3, the supplier's procedure should be used.

BOILER SAFETY

When it comes to duties involving the installation, operation, repair or servicing of boilers, the need for SAFETY can not be overemphasized. Much progress has been made over the years in the development of safety devices for boilers. There are still many ways, however, in which serious accidents can happen around boilers. A boiler operator or serviceman who is careless in the performance of his job poses a threat not only to his own safety, but to the safety of others. It seems that accidents somehow have a way of happening at a moment we least expect. All the more reason, therefore, for constant alertness and close attention to detail. Don't take chances! BE SAFETY CONSCIOUS!

The following list contains a number of SAFE practices which you should endeavor earnestly to FOLLOW in your work. It also contains a number of UNSAFE practices which you should make a vigorous effort to AVOID. You will find that actual on-the-job experience affords plenty of opportunity for acquiring additional information on boiler safety. If you are interested in further study on your own, a good place to start would be with a review of the material in section 2, chapter 6, of *U. S. Navy Safety Precautions,* OPNAV 34P1 (1953).

NEVER	***ALWAYS***
NEVER fail to anticipate emergencies. Don't wait until something happens before you start thinking.	ALWAYS study every conceivable emergency and know exactly what moves to make.
NEVER start work on a new job without tracing every pipeline in the plant and learning the location and purpose of each and every valve regardless of size. Know your job!	ALWAYS proceed to proper valves or switches rapidly but without confusion in time of emergency. You can think better walking than running.
NEVER leave an open blowdown valve unattended when a boiler is under pressure or has a fire in it. Play safe, memory can fail.	ALWAYS check water level in the gage glass with the gage cocks at least daily—also at any other time you doubt the accuracy of the glass indication.
NEVER allow sediment to accumulate in gage-glass or water-column connections. A false water level may fool you and make you sorry.	ALWAYS blow out each gage-line and water-column connection at least once each week. Forming good habits may mean longer life for you.
NEVER give verbal orders for important operations or report such operations verbally with no record. Have something to back you up when needed.	ALWAYS accompany orders for important operations with a written memorandum. Use a log book to record every important fact or unusual occurrence.

NEVER light a fire under a boiler without a double check on the water level. Many boilers have been ruined this way.	ALWAYS have at least one gage of water before lighting off. The level should be checked by the gage cocks.
NEVER light a fire under a boiler without checking all valves. Why take a chance?	ALWAYS be sure blowdown valves are closed, and proper vents, water-column valves, and pressure-gage cock are open.
NEVER open a valve under pressure quickly. The sudden change in pressure, or resulting water hammer, may cause piping failure.	ALWAYS use the bypass if one is provided. Crack the valve from its seat slightly and await pressure equalization. Then open it slowly.
NEVER cut a boiler in on the line unless its pressure is within a few pounds of header pressure. Sudden stressing of a boiler under pressure is dangerous.	ALWAYS watch the steam gage closely and be prepared to cut the boiler in, opening the stop valve only when the pressures are nearly equal.
NEVER bring a boiler up to pressure without trying the safety valve. A boiler with its safety valve stuck is nearly as safe as playing with dynamite.	ALWAYS lift the valve from its seat by the hand lever when the pressure reaches about three-quarters of popping pressure.
NEVER take it for granted that the safety valves are in proper condition. The power plant is no place for guess work.	ALWAYS raise the valve from its seat with the lifting lever each day the boiler is under pressure. Test by raising to popping pressure once each week.
NEVER increase the setting of a safety valve without authority. Serious accidents have occurred from failure to observe this rule.	ALWAYS consult the CEC officer in charge of the plant, your CPO, or other proper superior and accept his recommendations before increasing the safety-valve load.
NEVER change adjustment of a safety valve more than 10 per cent. Proper operation depends on the proper spring.	ALWAYS have the valve fitted with a new spring and restamped by the manufacturer for changes over 10 per cent.

Never tighten a nut, bolt, or pipe thread under steam or air pressure. Many have died doing this.	Always play safe on this rule. The one that is going to break does not have a special warning sign.
Never strike any object under steam or air pressure. This is another sure path to the undertaker's.	Always play safe on this rule, too. You can't tell which straw might break the camel's back.
Never allow unauthorized persons to tamper with any steam-plant equipment. If they don't injure themselves, they may cause injury to you.	Always keep out loiterers, and place plant operation in the hands of proper persons. A boiler room is not a safe place for a club meeting.
Never allow anyone to enter a boiler without proper protecting signs. Do not remove signs until you have personally checked that everyone is clear.	Always put a sign WORKMAN INSIDE on boiler at the point the man enters. Lock all valves that might endanger him if opened accidentally.
Never allow major repairs to a boiler without authorization.	Always consult the CEC officer in charge of the plant, your CPO, or other proper superior before making any major repair to a boiler.
Never light a burner without a torch. You can't dodge a furnace blast.	Always assume delayed ignition is going to cause a furnace explosion. Use proper ignition methods.
Never attempt to light a burner without venting the furnace until clear. Burns are painful.	Always allow draft to clear furnace of gas and dust for several minutes. Change draft conditions slowly.
Never fail to report unusual behavior of a boiler or other equipment. It may be a warning of danger.	Always consult someone in authority. Two heads are better than one.

QUIZ

1. What are the three major phases of boiler operation?
2. What should you do if operating a boiler and the water drops below safe operating level?
3. In removing a boiler from service, when do you drain it?

4. What is the advantage in cleaning boiler tubes while they are hot?
5. What is the maximum thickness specified for a furnace brick wall joint?
6. When is it necessary to boil out a boiler with a solution of boiler compound?
7. What are three types of power-driven outfits for cleaning boiler tubes?
8. In cleaning the interior of boiler tubes, why should you avoid stopping the cleaning tool at any point inside the tube?
9. What are three unsatisfactory conditions in tubes that make replacement necessary?
10. In replacing tubes in a fire-tube boiler, what is the purpose of beading the tube ends?
11. What are the essential parts of a tube expander?
12. Where on the boiler setting do leaks usually start?
13. How should you go about testing the operating condition of safety valves?
14. What should you look for in checking the discharge piping leading from blowoff valves?
15. What defects should you look for in checking the float of a float-type steam trap?
16. After the oil burner is stopped, there should be no dribble of oil into the furnace. Why?
17. What should you do if a raw, stingy flame in the oil burner seems to be caused by air in the pump?
18. What is the purpose of a hydrostatic test?
19. Following all hydrostatic tests, why should steam pressure be raised to lift the safety valves?
20. Why is testing of boiler water necessary?
21. Why is boiler water treated with tannin?
22. To what temperature should the sample for the sodium sulfite test be cooled?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

MEET THE UTILITIES MAN

1. The utilities of a naval base include the plants, systems, and equipment which provide those services essential to the health and welfare of personnel.

2. Utilities Man is included in group VIII, the construction or Seabee group of ratings.

3. Practical factors are qualifications which include minimum skills and abilities required for advancement, and which can best be demonstrated by performance.

4. Examination subjects are qualifications which include the minimum knowledges required for work performance, and which can best be shown by means of a written examination.

5. The Seabees were officially established on 5 January 1942.

6. The Bureau of Yards and Docks exercises technical control over the organization, equipment, and operational procedures of the Seabees.

7. The five companies which usually compose the basic military organization of a mobile construction battalion are the Headquarters Company and Companies A, B, C, and D.

8. One of the best ways to get to know your men is by talking with them.

9. Publications may be obtained from your training officer.

CHAPTER 2

PLUMBING

1. Plumbing is the art of installing in buildings the pipes, fixtures, and other apparatus for bringing in the water supply and removing the liquid and water-carried wastes.

2. For sewers and drains, which make up that part of the plumbing system installed belowground, four principal kinds of pipe are used: cast iron, acid-resistant cast iron, clay, and asbestos-cement.

3. If laid in unstable soil, vitrified clay pipe will sag and crack.

4. Asbestos-cement pipe comes in standard lengths of 13 feet; half-lengths are also available.

5. Because lead bends easily, lead pipe must be well supported.

6. Bushings are devices which can be screwed into the end of fittings or valves to decrease the size of the end opening.

7. The monkey wrench is the tool to select for hexagonal nuts, valves, and fittings.

8. The three-wheel cutter is of particular advantage when it is impossible to make a full turn with the wheel-and-roll cutter, as in overhead pipework.

9. Purpose of reaming is to remove the burr left on the inside of pipe after cutting or threading.

10. Before bending, copper pipes should be filled to keep them from flattening or collapsing at the bend.

11. The term "roughing-in" refers to the water supply and waste pipes which make up that part of the plumbing system usually concealed in the walls and floors, and which are usually installed while the building is being framed.

12. The check valve consists of two types: the swing check and the lift check.

13. Five different methods commonly used in measuring pipe include: (1) end to center; (2) center to center; (3) end to back; (4) center to back; and (5) back to back.

14. Joints in cast-iron soil pipe are generally made by calking.

15. Threaded pipe joints are commonly used on galvanized steel and galvanized wrought-iron pipe.

16. The butt joint consists of two ends of pipe which have been butted together, alined, and welded.
17. Copper tubing is usually joined by solder.
18. Because of the weight imposed by pipes and water, hangers are needed to provide support for overhead pipework and keep it in alinement.
19. In a water pipeline, flow is achieved by gravity or by use of a pumping system.
20. Trenches for sewer and drain pipe should be about 2 feet in width.
21. Purpose of insulation in plumbing is to prevent pipes from coming into contact with the outside atmosphere.
22. If lead must be poured into a wet hub, sprinkle powdered rosin or oil in the socket to reduce the tendency of the molten lead to fly out.
23. The term "trap seal" refers to the water which is held in the bent portion of a fixture trap.
24. Vents for water closets are connected above the flush tank.
25. A main vent is a vertical length of pipe which connects fixture vents to the main soil and waste vent.
26. A unit vent is used for the purpose of venting two traps to a single vent pipe.
27. Soil pipe branches are horizontal branch takeoffs which are used to connect various fixtures and the vertical stack.
28. Do not put more than 8 fixtures on any one circuit; if you have more than 8 fixtures to be circuit-vented, use 2 circuits.
29. The main soil and waste stack is installed in a vertical position.

CHAPTER 3

PLUMBING REPAIRS

1. On a compression faucet the seat washer is located at the end of the valve stem.
2. When a new washer fails to stop a leaky faucet, the trouble is a scored valve seat.

3. The closet auger is a good tool to use when a closet bowl is so clogged up that it can not be cleared with a force cup.
4. The best remedy for a fractured or ruptured pipe is replacement with a new section.
5. Wrap the tape tightly around the pipe and have it extend about 2 inches above and below the leak.
6. To repair a defective seam, first drain the water tank dry.
7. When the closet bowl is connected to the flush tank by means of a plated elbow, both the bowl and tank are a separate unit and one can be removed without removing the other.
8. During refilling of the flush tank, water passes through the refill tube and into the overflow pipe, and thence to the closet water trap.
9. In locating the source of trouble in the inlet valve assembly, check for the following defects: a leak in the float ball, a bent float arm, a worn washer on the bottom of the plunger, or a worn valve seat.
10. A small leak in a copper float ball can be remedied by soldering.
11. If the stopper ball has lost its elasticity, replace with a new one.
12. Heat should not be applied at the middle of a frozen section of pipe because the expansion of heated water would burst the pipe.
13. When variations of pressure at showers only occur when other outlets are open, you can usually correct the trouble by installing automatic mixing valves.
14. At the first sign of seepage, redisk or regrind the valve at once.
15. In closing a valve, to give the handle a quick, fast turn is likely to cause water to hammer on the valve.

CHAPTER 4

SEWAGE DISPOSAL AT ADVANCED BASES

1. Sewage poses a danger to health because of bacteria discharged by victims or carriers of infectious diseases.
2. The greater part of sewage is water.

3. If soil conditions permit, pit latrines should be dug from 20 to 30 feet.
4. The pit of a latrine is kept sanitary by spraying the pit walls and contents daily with crude oil, DDT, or sodium-arsenite spray.
5. Urine troughs should be scrubbed daily.
6. The liquids piped into cesspools seep into the soil.
7. Septic tanks should be inspected monthly.
8. You can help equalize the sludge depth throughout the sludge chamber of an Imhoff tank by reversing the flow every month.
9. In the storing of sludge in the Imhoff sludge chamber a maximum height of 2 feet below the flow chamber slot is desired.
10. In a clean Imhoff tank, you can hasten the ripening of sludge by seeding it with digested sludge, or by letting some fresh water into the sludge chamber.
11. Burial is the common method of garbage disposal in temperate climate areas.
12. A snow hole should be placed near a rock or terrain feature to make sure other troops will not place a tent on the same spot at a later date.
13. The bags are disposed of later by dumping on the ice of adjacent bodies of water.
14. Permafrost is permanently frozen ground.
15. After removal, the sludge should be taken to some remote spot from the camp, dumped, sprayed with gasoline and burned.
16. Tin cans and other nonedible trash can be crushed and then placed on the ice of adjacent ponds, rivers, and streams.

CHAPTER 5

ROUTINE DUTIES IN A SEWAGE DISPOSAL PLANT

1. Remove the grit from the grit chamber when the chamber is 50 to 60 percent full.
2. Fine screening should be used to remove coarse and fine suspended solids in sewage.

3. The cutting teeth of the comminutor should be inspected monthly.
4. Sewage flows through a plain sedimentation tank at 30–75 feet per hour.
5. Cleanliness is the chief answer to the odor control problem with septic tanks.
6. The temperature for heated sludge digestion tanks should be between 95°–100° F.
7. In a sludge digestion tank, 4 feet of sludge should be left for seeding purposes.
8. From 8 to 12 inches is the recommended maximum thickness of sludge for drying on a sand bed.
9. The five secondary treatment processes are (1) filtration, (2) secondary settling, (3) activated sludge, (4) contact aeration, and (5) subsurface irrigation.
10. The activated sludge process will remove 90 to 95 percent of the suspended solids.
11. Sludge is removed from contact aerators about once every 4 hours.
12. Chlorine is used at sewage plants to control odors, to facilitate treatment, and to disinfect the final effluents.

CHAPTER 6

BASIC REFRIGERATION

1. The process of refrigeration involves the removal of heat from a confined space so that the temperature within the refrigerated space is lower than that of the surrounding atmosphere.
2. Latent heat is the heat necessary to cause 1 pound of a substance to change its state at the boiling or freezing temperature.
3. Heat is a form of energy.
4. Heat quantity is measured in Btu's.
5. The quantity of heat required to melt 1 pound of 32° ice to 1 pound of 32° F water is 144 Btu's.

6. The three methods of heat transfer are conduction, convection, and radiation.

7. The method of heat transfer by heat waves is known as radiation.

8. In refrigeration, convection is the most important method of heat flow.

9. Freon-12 is the refrigerant used most by the Navy.

10. A primary refrigerant is one that cools by absorbing latent heat.

11. A secondary refrigerant is one that cools by absorbing sensible heat.

12. A refrigerant is a medium by which heat is removed from the region being cooled and conveyed to a higher temperature level where the absorbed heat can be discharged.

13. The four basic parts of a vapor compression refrigeration system are: (1) cooling coil; (2) compressor; (3) condenser; and (4) expansion valve.

14. At atmospheric pressure, Freon-12 has a boiling point of −21.6° F.

15. Compressed-gas cylinders of refrigerants should be stored in a cool dry place, where they will not be exposed to direct sunlight for long periods.

16. Relative humidity is the amount of moisture in the air at a given temperature, expressed as a percentage of the maximum amount of moisture the air can hold at that same temperature.

17. Specific humidity is the amount of water vapor in air, expressed in grains per pound of dry air.

18. The term dehumidification refers to the process of the removal of moisture from the air.

19. The expansion valve controls the flow of liquid refrigerant from the receiver into the evaporator.

20. Two principal differences between new and old models of air-conditioning units are: (1) new models have greater cooling capacity; and (2) new models usually have condensers cooled by water instead of air.

CHAPTER 7

ENGINES, PUMPS, AND COMPRESSORS

1. An internal combustion engine is a machine that produces mechanical energy by burning fuel within a confined space (the engine cylinder).
2. The four strokes that take place in a 4-stroke cycle engine are: (1) inlet or intake stroke; (2) compression stroke; (3) expansion or power stroke; and (4) exhaust stroke.
3. The diesel engine produces combustion by using the heat of compression.
4. Most gasoline engines operate on the four-stroke cycle.
5. In the gasoline engine, an electric spark is produced by the spark plug to ignite the air-gas mixture.
6. On one stroke a suction valve opens and liquid is let into a chamber. On the second stroke the suction valve closes, the piston comes down and forces the liquid out through a discharge valve.
7. All pumps have a water end and a power end.
8. The old-fashioned well pump led to the development of the steam-operated reciprocating pump.
9. The throttle valve should be opened slowly in order to warm up gradually.
10. The first thing to do, if the steam-operated pump fails to start, is close the steam and exhaust valves.
11. The cushioning valves are adjusted to give a pump a full stroke.
12. Use kerosene to clean steam valves and valve gear of a pump.
13. The rotating element in a centrifugal pump is known as the impeller.
14. The outer part of the casing of a centrifugal pump is called the volute.
15. When the pump is up to proper speed, open the discharge valve.
16. The hi-lift pump operates on the principle of squeezing water instead of pushing or whirling it.

17. The packing material is held in place by flanged, bolted, or threaded gland bushings.

18. Check the pump for misalinement, vibration, bent shafts, or scored sleeves.

19. In securing the air compressor, the purpose of opening the drain cock on the bottom of the air receiver is to remove moisture, air, and oil.

20. Most air compressor explosions are due to the presence of oil or kerosene vapor, dirt, or dust in the air used. Be sure the machine has clean, dry air!

CHAPTER 8

WATER TREATMENT PROCESSES

1. Dissolved impurities are organic or inorganic materials or chemicals which may cause an unpleasant taste, color, or odor in the water.

2. The method of treatment using floc-forming chemicals to form floc or precipitate in the water is known as flocculation, or coagulation.

3. The purpose of a *p*H reading is to determine the intensity of alkalinity or acidity of the water.

4. The *p*H determination test is made to find at what *p*H floc will best form.
5. The ideal detention period for settling after slow mixing is about 1½ hours.
6. Two types of rapid-sand filters used in filtration are: the gravity type and the pressure type.

7. Diatomite filters are backwashed by reversing the flow of water and drawing filtered water from the storage tank through the filter.

8. "Disinfection" refers to the process of killing or removing any harmful organisms that cause disease.

9. Less effective hypochlorite compounds, such as bleach (24 to 35 percent available chlorine), may be used if approved by the medical officer.

10. Chlorine demand means the minimum amount of chlorine required to kill all the harmful organisms in the water.

11. Chlorine dosage indicates the sum of chlorine demand plus chlorine residual.

12. The purpose of the chlorine-residual test is to determine the chlorine content of the water.

13. One ppm chlorine residual means 8.34 pounds of available chlorine to a million gallons of water.

14. Two ways of removing unpleasant tastes and odors in water are (1) by the process of aeration; and (2) by passing the water through beds of activated carbon.

15. Chlorination will prevent distilled water from becoming contaminated.

16. Orthotolidine is the color agent (indicator) used in making the chlorine-residual test.

17. To lower the *p*H during the process of flocculation, increase the amount of feed from the alum feed pot.

18. A good floc is from ⅛ to ¼ inch in diameter.

CHAPTER 9

PORTABLE WATER TREATMENT UNITS

1. The Lyster bag is used primarily as a dispensing unit for purified or distilled water.

2. A double-faced filter disk is used in the kit-type purification unit.

3. This relieves the load on the filter, increases its capacity, and uses less filter-aid.

4. The diatomite filter depends upon the powder-like diatomaceous earth used as a filter-aid solution for its efficiency.

5. The initial filtering mat of diatomaceous earth is known as the precoat.

6. Body feed is used during the filter run to keep the filter coat (cake) porous.

7. The backwash consists of three operations: loosening of the precoat and filter cake; flushing out of the sludge; and actual backwashing of the filter elements and the filling shell with filtered water.

8. As the rate of flow falls, the dial settings on the filter-aid feeder and the hypochlorite feeder should be reduced to maintain the proper dosage.
9. As the first step in securing a diatomite filter, backwash the filter thoroughly.
10. The hypochlorination unit issued to advanced bases has a capacity of 2 to 400 gpm when installed as a by-pass.
11. The minimum recommended water pressure in a hypochlorination unit is 10 pounds per square inch.
12. The recommended speed for a hypochlorination unit when maximum flow is reached is 12 strokes per minute.
13. Soda ash is used to precipitate "hardness" of water.
14. At a speed of 12 strokes per minute, the hypochlorinator will pump 60 gallons of solution per day when the stroke control handle is set at 10 on the dial.
15. Superchlorination means the application of more chlorine than is needed to maintain the proper chlorine residual, followed by dechlorination to remove the surplus.

CHAPTER 10

DISTILLATION UNITS

1. The ultimate product resulting from condensation is called distillate.
2. The heat to continue the process is generated by compressing the vapor to a higher pressure and temperature and discharging it back to the heating element of the same distillation unit (still).
3. Heat which is given up through the discharge of distillate, radiation, and other causes is replaced by utilizing the raw water taken into the system, a compressor, and auxiliary heat.
4. The maximum time that the 85-gph distillation unit should operate without being cleaned is 720 hours.
5. The essential components of the 85-gph and the 200-gph distillation units are: evaporator, heat exchanger, vapor compressor, diesel engine, pumps, piping, gages, and controls.
6. The three basic systems of flow in models DVC-8 and DVC-20 are raw water, distillate, and blowdown.

7. The concentrated water and salt solution taken from the bottom head is known as the blowdown.
8. The most important factor in the operation of any distillation unit is maintaining the proper heat balance.
9. The two functions of the vent condenser are to remove noncondensable gases from the distillate and to reclaim some of the heat of these gases and transfer it to the feed water.
10. About 2 gallons of raw water are needed to produce a gallon of distillate.
11. Complete drainage is necessary in the case of a prolonged shutdown or where freezing is likely.
12. The chemical method is used more often to remove scale than the mechanical method.
13. The chemical method of scale removal is not practicable when the scale is not soluble in acid or when the scale formation is excessively deep.
14. Either hydrochloric acid or niter cake may be used as the chemical cleaner.
15. In preparing the acid solution to remove scale, ALWAYS add acid to the water.
16. A shutdown of 5 minutes or less would be considered as being a short shutdown.
17. Operating troubles may be broken down into five major categories: general, evaporator, heat exchanger, compressor, and blowdown pump.
18. Particles suspended in the raw water are removed by the strainer.
19. The purpose of the heat exchanger is to heat the incoming raw water so that less heat will be needed inside the evaporator, and the plant will be more efficient.
20. If the raw water temperature is between 45° and 135° F., the unit will produce distillate within 1½ hours.

CHAPTER 11

ROUTINE DUTIES IN A WATER PURIFICATION PLANT

1. The dry feeder automatically feeds powdered chemicals, such as alum, into the water.

2. Quick agitation, followed by a gentle movement, is the best type of stirring when coagulating chemicals are mixed with the water.
3. The flocculator operates on a ferris-wheel principle.
4. The usual settling period in the coagulation-sedimentation basins is 6 hours.
5. The two types of rapid-sand filters are: the pressure type and the gravity type.
6. Chlorination also helps produce safe water.
7. Copper sulphate is the chemical usually used to check algae growths.
8. Usually 4 to 6 minutes is needed for backwashing a filter.
9. Small cracks in concrete reservoirs can be patched with a rich cement grout mixture.
10. The coagulation process removes some of the dirt and bacteria from the water.
11. Hypochlorinators are used for feeding solutions of high-test hypochlorite or other approved chlorine compound.
12. Wood alcohol can be used to clean chlorination equipment and piping.

CHAPTER 12

STEAM BOILERS

1. A boiler is a closed vessel in which steam is generated as a result of the combustion of fuel.
2. Superheated steam is steam which has been heated above the saturation temperature.
3. A stationary boiler is one having a permanent foundation and not easily moved or relocated.
4. In the fire-tube boiler, the products of combustion pass through the tubes and the water surrounds the tubes.
5. Oil is the fuel commonly used to fire the Scotch boiler.
6. The flow of gases in the Scotch boiler is toward the rear of the combustion chamber, then return by way of the tubes to the front, and out into the smoke box and stack breeching.

7. A handhole is an opening large enough to permit entry of the hand for cleaning, inspection, and repair to headers and tubes.

8. On bent-tube (water-tube) boilers the baffles usually are installed so that 70 to 80 percent of the heat will be absorbed by the inclined tubes between the lower and upper front drums.

9. Breechings are used to connect the boiler to the stack.

10. The root valve is located between the source of power and the prime mover.

11. If operating pressure is 400 psi or more, two water-gage glasses must be provided.

12. The water column is equipped with a high- and low-water alarm whistle.

13. An automatic feed-water regulator provides a means of automatic control of the water level in the boiler.

14. The two types of fusible plugs are the fire-actuated and the steam-actuated.

15. The safety valve is the most important boiler fitting.

16. With the huddling-chamber type of safety valve, blowdown adjustment is accomplished by means of an adjusting ring attached to the seat bushing. Raising this ring increases the blowdown; lowering it decreases the blowdown.

17. The main function of the oil burner is to prepare the fuel for combustion.

18. Two types of mechanical atomizers in fuel oil burners, which you are likely to find being used on Navy boilers, are: pressure and rotary.

19. The three parts of the thermodynamic steam trap are: a body, a cap, and a valve head.

20. A typical temperature controller consists of a regulating valve, a temperature bulb, a metal bellows, and the necessary tubing to connect the valve to the bellows.

21. Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam.

22. A Ledoux bell would be found on a steam flow meter.

23. A CO_2 meter is an instrument for determining, indicating, and recording the percentage of CO_2 in the products of combustion.

24. The fire point of an oil refers to the temperature at which the oil gives off sufficient vapor to remain ignited after flashing.
25. Water and sediment are the most common impurities in oil.

CHAPTER 13

OPERATION AND MAINTENANCE OF STEAM BOILERS

1. The operation of a boiler consists of three major phases: (1) preparing and starting, (2) operating, and (3) securing.
2. If the water goes below safe operating level, secure the burner until the water is returned to proper level by means of automatic or manual control.
3. When the boiler is cool enough that it can be entered, drain it.
4. Tubes are best cleaned while hot because then the soot is still dry and powdery.
5. Joints should never exceed one-sixteenth of an inch.
6. New boilers, or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound.
7. Three types of power-driven cleaning outfits are: electric motor-driven cleaner, pneumatic turbine-driven cleaner, and hydraulic turbine-driven cleaner.
8. Avoid stopping the cleaner at any point inside the tube as it may cut through the tube.
9. All badly warped tubes, tubes in which the belling is likely to give trouble, and tubes that leak after having been re-rolled must be replaced.
10. The tube ends are beaded to prevent pulling out.
11. The tube expander consists essentially of three rollers, a body, and a mandrel.
12. Leaks usually start around drums or other places where a strain is placed on the setting.
13. In testing the operating condition of safety valves, gently raise the valves off their seat by hand, first making sure there is sufficient pressure (75 percent of normal working pressure) to prevent straining the easing gear, as well as to blow the seat clean of dirt and scale.

14. Make sure the discharge piping is not mounted so rigidly that proper expansion and contraction will be affected.

15. Examine the float for leaks and deterioration.

16. If oil dribbles into the furnace after the oil burner is stopped, late ignition is likely to result.

17. If it appears that a raw, stingy flame is caused by air in the pump, open the petcock on the pressure gage to purge the air from the system.

18. A hydrostatic test is made to prove either the tightness of all parts of the boiler or the strength of the boiler and its parts.

19. This is to test and set the safety valves and to definitely determine the fitness of the boiler for use.

20. Testing of boiler water is necessary to determine whether the amount of chemical residuals required to maintain clean boiler surfaces is present.

21. Tannin is used to hold sludge in suspension.

22. The sample for the sodium sulfite test should be cooled to 70° F, or below.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

UTILITIES MEN (UT)

Quals Current Through Change 8

Rating Code No. 5800

General Service Rating

SCOPE

Utilities men install, operate, maintain, and repair pumps, stationary steam boilers, and water distillation and purification equipment; maintain and operate water supply and sewage disposal installations; install and operate stationary prime movers used to furnish utilities at advanced bases; perform plumbing and pipefitting work required at advanced bases; make chemical tests to determine safeness and potability of water.

Emergency Service Rating

Same as General Service Rating.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see Manual of Navy Enlisted Classifications, NavPers 15105 (Revised), codes UT–6100 to UT–6199.

Qualifications for Advancement in Rating	*Applicable Rates* *UT*
100 PRACTICAL FACTORS	
101 OPERATIONAL	
1. Select and use properly the following plumber's hand tools: Pipe wrench, pipe reamer, pipe threader, pipe vise and pipe cutter	3
2. Read simple working drawings and sketches	3
3. Operate and adjust pumps used at advanced bases for water supply, sanitation, and water purification	3
4. Cut and thread pipe; make threaded pipe joints. Place pipe lagging	3
5. Test boiler and feed water	3
6. Test water for *p*H and residual chlorine	3
7. Operate portable air compressors	3
8. Operate, adjust, and lubricate water distillation and purification equipment used at advanced bases	3
9. Operate stationary steam boilers used to supply heat or power to shore stations and advanced bases	3
10. Operate stationary diesel-powered prime movers used to furnish utilities at advanced bases	3
11. Work from working drawings and sketches	2
12. Make joints for high-pressure pipe lines; bend and fit copper tubing	2
13. Install water distillation and water purification equipment used at advanced bases	2
14. Install furnace brickwork for boilers	2
15. Lay drainage pipe to grade	2
16. Install stationary diesel-powered prime movers used to furnish utilities at advanced bases	1
17. Install and make operating adjustments and repairs to refrigeration and air conditioning equipment	1
18. Prepare sketches used in plumbing work	1
19. Install pumps used at advanced bases for water supply, sanitation, and water purification	1

Qualifications for Advancement in Rating	*Applicable Rates* *UT*
101 OPERATIONAL—Continued	
20. Act as chief operator of advanced-base water purification plants. Operate and maintain all moving equipment; inspect tanks, filters, and chambers; check and regulate valves controlling flow; chlorinate and chemically process raw water, make tests of water, record data, and control degree of treatment, safeness, and potability of water	1
21. Act as chief operator of advanced-base sewage disposal plants. Operate and maintain all moving equipment; inspect tanks, filters, chambers, and drying beds; check and regulate valves controlling flow; determine and add proper amounts of chemicals to sewage for stabilization; record data and control degree of treatment and stability of effluent	1
102 MAINTENANCE AND/OR REPAIR	
1. Inspect, pack, and replace oil seals on pumps used for water supply, sanitation, and water purification	3
2. Clean firesides and watersides, clean and adjust burners, and set and adjust valves of stationary steam boilers	3
3. Maintain pumps used at advanced bases for water supply, sanitation, and water purification	2
4. Repair furnace floors, walls, and linings for stationary steam boilers	2
5. Use power-driven equipment to clean boiler tubes	2
6. Replace defective boiler tubes	2
7. Repair water distillation and water purification equipment used at advanced bases	1
8. Repair and overhaul pumps used at advanced bases for water supply, sanitation, and water purification	1
9. Test, adjust, and recalibrate high-pressure and low-pressure gages	1
10. Repair air or water leakage in furnaces, pipelines, pipe fittings, and other parts of boilers	1

Qualifications for Advancement in Rating	*Applicable Rates* *UT*
103 ADMINISTRATIVE AND/OR CLERICAL	
1. Keep operational logs for equipment found in sewage disposal and water purification plants	3
2. Make estimates from working drawings, specifications, and sketches, of materials required for installation and repair of advanced-base utilities. (Excluding electrical distribution.)	1
3. Supervise and train men engaged in firing, servicing, and operating stationary steam boilers and auxiliary equipment used to supply power or heat at advanced bases	1
4. Prepare material requisitions and job work orders	1
5. Prepare operational reports on sewage disposal, water purification and supply, and stationary steam boiler plants	C
200 EXAMINATION SUBJECTS	
201 OPERATIONAL	
1. Selection and use of tools employed in the installation, operation, and maintenance of sewage disposal, water purification and supply, and steam boiler plants and of stationary diesel prime movers, motors, and compressors	3
2. Procedures, uses, and interpretations of residual-chlorine and *p*H tests	3
3. Uses and operation of pumps required for water supply, sewage disposal, and water purification at advanced bases	3
4. Principal parts and uses of stationary steam boilers and diesel prime movers employed to supply utilities at advanced bases	3
5. Methods of water purification and types of water purification equipment used at advanced bases	2
6. Methods of sewage disposal and types of sewage disposal equipment used at advanced bases	2
7. Methods of installing, operating, and maintaining advanced-base water purification and distillation units	1

Qualifications for Advancement in Rating	*Applicable Rates* *UT*
201 OPERATIONAL—Continued	
8. Methods of installing, operating, and maintaining stationary diesel prime movers	1
9. Relative degrees of purification obtained by chlorination, filtration, sedimentation, distillation, and flocculation	1
10. Power, fuel, water, and chemical requirements for operation of water purification equipment and sewage disposal plants	C
202 MAINTENANCE AND/OR REPAIR	
1. Repairing stationary steam boilers used to furnish heat and power at advanced bases	2
2. Repairing and overhauling pumps used at advanced bases for water supply, sanitation, and water purification	1
203 ADMINISTRATIVE AND/OR CLERICAL	
1. Functions of operational companies of a Construction Battalion	3
2. Safety precautions to be observed in operation and repair of sewage disposal, water purification and supply, and steam boiler plants, stationary diesel prime movers, motors, and compressors	3
3. Use of allowance lists of spare parts, tools, and consumable materials; procedures for maintaining an inventory and obtaining replacement parts and supplies	C
4. Principal sources of water for advanced bases and comparative safeness of various sources	C

300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER

Utilities Men advance to Warrant Equipment Foreman and/or to Limited Duty Officer, Civil Engineer Corps. (*See page iv-c.*)

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